CILCA 2017

VII Conferencia Internacional de

Análisis de Ciclo de Vida en Latinoamérica

12 al 15 de junio de 2017

Medellín - Colombia

Código ISBN: 978-958-8719-63-4

TABLA DE CONTENIDOS

Cordial Saludo

Asunto: Carta de introducción a memorias CILCA 2017

Apreciado lector

La Conferencia Internacional de Análisis de Ciclo de Vida en Latinoamérica, CILCA, es reconocida hoy en la comunidad de practicantes del ciclo de vida y por quienes vienen trabajando con un enfoque de ciclo de vida en la planeación y toma de decisiones en busca de un desarrollo sostenible.

CILCA es un evento bianual que se lleva a cabo en diferentes países de Iberoamerica y convoca a expertos e interesados de todo el mundo. La primera conferencia se llevó a cabo en 2005 en San José de Costa Rica ganando cada vez más y reconocidos asistentes pasando por Sao Paulo (Brasil) en el 2007, Pucón (Chile) en 2009, Coatzacoalcos (México) en el 2011, Mendoza (Argentina) en 2013, Lima (Perú) en 2015 y en está ocasión Medellín (Colombia) para el año 2017.

La Red Iberoamericana de Ciclo de Vida, la Red Colombiana de Ciclo de Vida y la Iniciativa de Ciclo de Vida PNUMA/SETAC organizaron esta séptima edición de la Conferencia Internacional de Ciclo de Vida en Latinoamérica (CILCA) del 12 al 15 de Junio del 2017 en Medellín, Colombia.

La temática central de CILCA 2017 estuvo en la mirada del aporte de la perspectiva de ciclo de vida hacia el cumplimiento de los Objetivos de Desarrollo Sostenible y es por esto que en el presente libro de memorias encontrará los resúmenes de las 68 ponencias orales aceptadas de más 200 enviadas a nivel internacional, adicionalmente los resúmenes aceptados como poster en las temáticas de Desarrollo Rural, Gestión de residuos, Estudios de caso en ACV, Huella de carbono y huella de agua, Bases de Datos, ACV Social, Ecoeficiencia, Diseño para la sostenibilidad, Economía verde, Políticas sostenibles, gestión de recursos, educación y promoción del ACV, estilos de vida sostenibles y mercadeo verde.

Esperamos que tanto CILCA 2017, como la calidad de las presentaciones orales y poster, aporte en la construcción de un planeta más sostenible y que este tipo de encuentres fortalezca la creación de redes y el trabajo con un enfoque de ciclo de vida.

Cordialmente

Carlos Naranjo
Presidente CILCA 2017
Presidente Red Iberoamericana de Ciclo de Vida

CILCA 2017

VII Conferencia Internacional de

Análisis de Ciclo de Vida en Latinoamérica

12 al 15 de junio de 2017

Medellín - Colombia

PROGRAMACIÓN

Lunes, 12 de junio

Hora	Salón 1 UNEP	Salón 2 Software	Salón 3 Social LCA	Salón 4 LCIA/EPD	Salón 5 Aplicación
8:00 a.m.	**PNUMA** Life Cycle Thinking for sustainable value chain and Eco-Innovation Training for Latin-America and Caribbean 33-201	Software SimaPro 33-202	**Green Delta** Social Life Cycle Assessment – Understanding social impacts with openLCA and specific databases 33-204	**EPD System** Curso: Reglas por Categoría de Productos y Declaraciones Ambientales del Tipo III 33-301	**Sostenipra-ICTA-UAB.** Ecodiseño de la teoría a la práctica. Herramienta edTOOL 33-302
12:00 p.m.	Almuerzo libre	Almuerzo libre	Almuerzo libre	Almuerzo libre	Almuerzo libre
1:30 p.m.	**PNUMA** Life Cycle Thinking for sustainable value chain and Eco-Innovation Training for Latin-America and Caribbean 33-201	Software Umberto 33-202	**Green Delta** Social Life Cycle Assessment – Understanding social impacts with openLCA and specific databases 33-204	**thinkstep** How to evaluate Circular Economy using LCA and LCA software 33-301	**Quantis, CADIS, CNPML.** Advance in Water Footprint Assessment – Latin America 33-302
5:30 p.m.	Cierre de sesión	Cierre de sesión	Cierre de sesión	Cierre de sesión	Cierre de sesión

Hora	Martes, 13 de junio Business perspectives on LC contribution to SDG				Miércoles, 14 de junio LC contribution to sustainability goals			Jueves, 15 de junio Enhancing collaboration and communication towards mainstreaming LCA and SDG	
8:00 a.m. 8:20 a.m.	Apertura: **Alcaldía, UNEP, RICV** Auditorio Fundadores				LC contribution to sustainability goals **Mark Goedkoop** Auditorio Fundadores			"Evolution and future of LCIA and sustainability indicators in Europe and LatinAmerica". **Francesc Castells** Auditorio Fundadores	
8:40 a.m. 9:00 a.m. 9:20 a.m.	Business perspectives on LC contribution to SDG Latin America, Europe and Africa. **Nydia Suppen** Auditorio Fundadores				LC contribution to sustainability goals **Guido Sonneman** Auditorio Fundadores			Sustainable Lifestyles **Adriana Zacarias** Auditorio Fundadores	
9:40 a.m.	Refrigerio			Refrigerio	Refrigerio		Refrigerio	Refrigerio	Refrigerio
10:00 a.m. 10:20 a.m. 10:40 a.m. 11:00 a.m. 11:20 a.m. 11:40 a.m.	LCA-Rural development Auditorio Fundadores	Waste Management Aula Fabricato (27-101)	Curso **Ecoinvent** SRI Project (sponsor) 33-202		Databases Auditorio Fundadores	Ecoefficiency and LCA Aula Fabricato (27-101)	Curso **Vertech Group** (sponsor) 33-201	LCA and Sustainable Cities Auditorio Fundadores	Educational and LCA Promotion/ Sustainable Lifestyles Aula Fabricato (27-101)
12:00 p.m.	Almuerzo Libre			Almuerzo Libre	Almuerzo Libre		Almuerzo Libre	Almuerzo Libre	Almuerzo Libre
1:45 p.m. 2:05 p.m. 2:25 p.m. 2:45 p.m. 3:05 p.m. 3:25 p.m.	Case studies in LCA Auditorio Fundadores	Carbon and Water footprint Aula Fabricato (27-101)	Curso **Ecoinvent** SRI Project (sponsor) 33-202	**World Resources Forum.** ISO Guidance Principles for the Sustainable Management of Secondary Metals. 33-201	Social LCA Auditorio Fundadores	Design for sustainability Aula Fabricato (27-101)	Curso **Vertech Group** (sponsor) 33-201	Green Economy and Sustainable Policies/ Resource Management Auditorio Fundadores Refrigerio	Green Marketing: Ecolabelling and EPDs Aula Fabricato (27-101) Refrigerio
3:45 p.m.	Refrigerio			Refrigerio	Refrigerio		Refrigerio	Plenaria Enhancing collaboration and communication towards mainstreaming LCA (UNEP, Ministerio, FSLCI) Auditorio Fundadores	
4:00 p.m. 4:40 p.m. 5:00 p.m. 5:20 p.m. 5:40 p.m. 6:00 p.m.	Plenaria Business perspectives on LC contribution to sustainability goals (ANDI, Pacto Global, UNEP, WRF) Auditorio Fundadores				Plenaria LC contribution to sustainability goals (WRF, UNEP, Int JLCA, Revista LALCA) Auditorio Fundadores			Clausura CILCA 2017 Bienvenida CILCA 2019 Auditorio Fundadores	

Carbon and Water Footprint

CILCA 2017

VII Conferencia Internacional de

Análisis de Ciclo de Vida en Latinoamérica

12 al 15 de junio de 2017

Medellín - Colombia

LCA OF WATER MANAGEMENT ALTERNATIVES IN A POULTRY SLAUGHTERHOUSE

EVALUACIÓN DE ALTERNATIVAS DE GESTIÓN DEL AGUA EN UNA PLANTA DE BENEFICIO AVÍCOLA CON ACV

PhD(c). Yelitza Angélica Zorrilla-Ortega*,
PhD(c). Juan Pablo Silva-Vinasco*,
PhD. Pablo César Manyoma-Velásquez,**
PhD. Valentina Prado***

* Universidad del Valle, Facultad de Ingeniería, Programa de Ingeniería Sanitaria y Ambiental y el Programa de Ingeniería Industrial**,
Calle 13 # 100-00, Cali, Valle, Colombia.
Tel: +57 2 3212183, Fax: +57 2 3312175.
E-mail: {yelitza.angelica.zorrilla, juan.silva, pablo.manyoma} @correounivalle.edu.co
*** Universidad de Leiden, Facultad de Ciencias, Departamento de Ecología Industrial-CML.
Van Steenis Building Einsteinweg 2 2333 CC, Leiden, Holanda.
Tel +31 71527 1496.
E-mail: v.prado@cml.leidenuniv.nl

ABSTRACT:

With only 2.5% of fresh water available to satisfy human activities in the world, there will be strong conflicts between the different users of this resource. Large demanders such as the food sector pose a challenge, due to their diversity and composition. In the case of Colombia, many of these companies, mainly small and medium, do not carry out an adequate water management without the implementation of cleaner production alternatives based on the rational use of water resources. The main effluent treatment systems are "pipe end", without reuse or reuse of water in other processes and in some cases with difficulties to comply with environmental regulatory yields. This study was based on a preliminary diagnosis of Life Cycle Assesment (LCA) in a Poultry Slaughtering Plant (PSP), aiming to strengthen sustainable production processes. For this end, the proposal evaluates two variables of water management, one focused on reducing water use in some stages of production and the other evaluates alternative cleanings products. The foregroud inventory was built with primary data and backgroud processes are gathered from Ecoinvent 3.2. The SimaPro 8.2 software and RECIPE-Midpoint method were used. The results allow the identification of environmental critical points, for which alternatives are proposed in order to evaluate implications, and with this, to establish a better environmental performance.

Keywords:

Water Management; Poultry Slaughterhouse; LCA; Colombia.

Resumen:

Con solo el 2,5% de agua dulce disponible para satisfacer las actividades humanas en el mundo, se plantean fuertes conflictos entre los diferentes usuarios de este recurso. Grandes demandantes como el sector de alimentos plantean un reto, por su diversidad y composición. En el caso de Colombia, muchas de estas empresas, principalmente pequeñas y medianas, no realizan una adecuada gestión del agua en cuanto a la implementación de alternativas de producción más limpia basadas en el uso racional del recurso hídrico. Los principales sistemas de tratamiento de efluentes son de "final de tubo", sin un aprovechamiento, reúso o reutilización de aguas en otros procesos y en algunos casos con dificultades para cumplir con los rendimientos normativos ambientales. Por tanto, para fortalecer procesos productivos sostenibles, y con base en un diagnóstico preliminar de análisis de ciclo de vida en una planta de sacrificio avícola, el presente estudio propuso evaluar dos alternativas de gestión del agua en dicha planta, una enfocada en reducir el uso del agua en las etapas de producción y la otra evalúa alternativas en los productos de limpieza. El inventario de primer plano se construyó con fuente primaria y para los procesos de fondo se complementó con Ecoinvent 3.2. Se utilizó el software SimaPro 8.2 y el método RECIPE-Midpoint. Los resultados permiten identificar los puntos críticos ambientales con mayor presión, para las cuales se proponen alternativas donde se evalúan sus implicaciones y con ello, poder establecer un mejor desempeño ambiental.

Palabras clave:

Alternativas de manejo del agua; Planta de beneficio avícola; Ciclo de Vida, Colombia.

1| INTRODUCCÍON

Aunque las empresas han realizado acciones en pro del cuidado del ambiente es mucho lo que falta por hacer. Diferentes estrategias de manejo del agua se han empleado al interior de estas, algunas enfocadas en abastecimiento para minimizar el consumo (Gomes et al., 2013; Koppol et al., 2004); las configuración de las redes de agua para una reutilización máxima con menor caudal efluente (de Arruda et al., 2011); y las propuestas para optimizar las unidades de procesos como las torres de enfriamiento (Gololo, 2013). Otros se han enfocado al tratamiento del agua residual industrial, definiendo criterios de selección para el cumplimiento de estándares ambientales (Martínez-Gómez et al., 2013; Meerholz & Brent, 2013) hasta re-conceptualizando el objeto del tratamiento, cambiando el cumplir estándares para verter hacia tratarlo para aprovecharlo internamente (Bahri, 2013). Otras alternativas han planteado el diseño de la red de descarga tipo descentralizada para reducir el impacto de los grandes volúmenes de efluentes (Statyukha et al., 2008); como el caso de Oconnor et al., (2013) que evalúa el reúso en irrigación del agua residual industrial.
El generar una optimización en la demanda de agua, un menor volumen de agua residual y considerar el aprovechamiento de efluentes, permite volver el proceso más eficiente y reducir el problema de contaminación por efluentes líquidos industriales. Es por ello, que el presente estudio tiene como objetivo evaluar dos alternativas de gestión del agua en una planta de sacrificio avícola por medio del análisis de ciclo de vida y así validar cuál de estas contribuye a un menor impacto ambiental y una acertada selección que conlleve a una mejor gestión del agua.

2| METODOLOGÍA

Características de la Planta: El estudio se realizó en una planta mediana con capacidad promedio de sacrificio de 13560 aves/día. El proceso está conformado por las etapas de recepción, aturdimiento, degüelle, escaldado, desplume, eviscerado, lavado de canales, enfriamiento y empacado. Además, cuenta con operaciones auxiliares como: lavado de canastillas, limpieza de camiones, generación del hielo, potabilización del agua y tratamiento de efluentes.

Formulación de Alternativas: Las alternativas consideradas se apoyaron en las visitas técnicas y la literatura. La línea base se identificó como [A0], donde hay un consumo normal de agua y emplea un detergente convencional. La Alternativa [A1] fue el manejo en seco de subproductos en áreas de escaldado/eviscerado con reducción del consumo de agua y usando detergente convencional. [A2] Cambia la calidad del detergente y el consumo de agua es normal.

El inventario se construyó con información primaria, cuantificando las entradas de consumo de agua, energía, insumos de limpieza y ACPM para calderas. Impactos relacionados con la granja y el transporte fueron excluidos del sistema evaluado. Como residuo se consideró el volumen vertido de agua residual. Los subproductos (sangre, plumas y vísceras) no están incluidos en el sistema, por ser aprovechados por un tercero. Por lo tanto, la asignación de los impactos fue atribuida al pollo en canal. Se obtuvo un sólo producto final y este coincide con la unidad funcional seleccionada de una tonelada de canal de pollo listo sin vísceras -CPL. Se utilizó el software SimaPro 8.2, la base de datos Ecoinvent 3.2, con allocation default-unit y el método de evaluación de impacto RECIPE-Midpoint, tipo jerárquico – incluye 17 categorías de impacto de las cuales se discuten 7 de acuerdo con las principales áreas de protección recursos naturales, salud humana y entorno natural.

3| RESULTADOS Y DISCUSIÓN

El funcionamiento del proceso productivo de línea base [A0], arrojo como principales contribuyentes en la categoría de impacto Agotamiento agua -WD, las áreas de desplume (33,1%) y eviscerado (32,9%); los detergentes como insumos de limpieza, fueron representativos en las demás categorías, con rangos superiores al 28% (Figura 1).

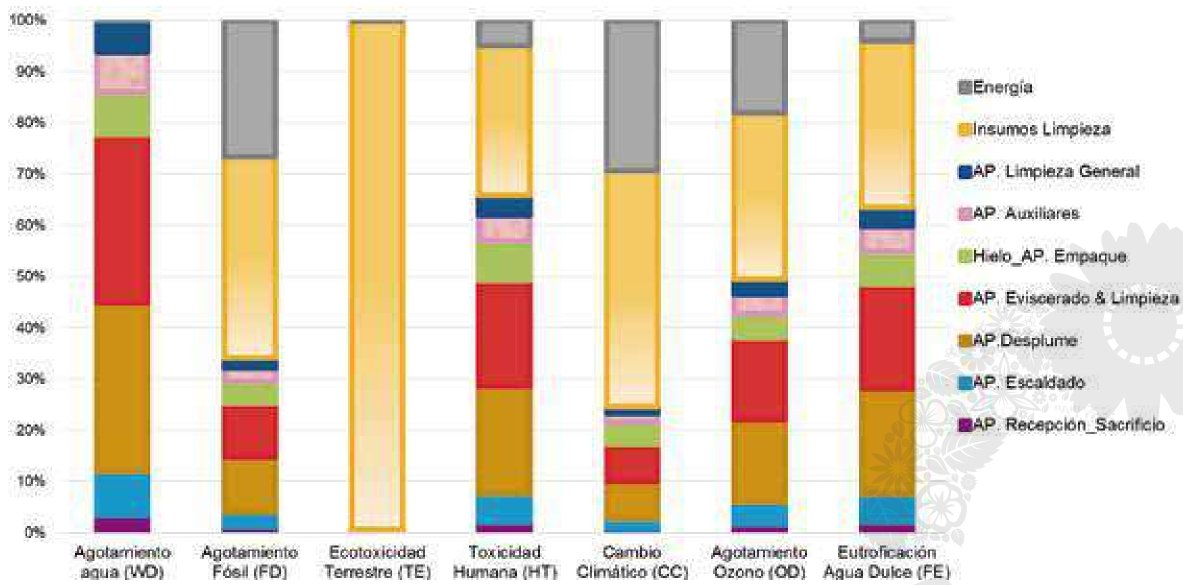


Figura 1. Análisis de contribución por categorías de impactos para A0

A partir de las visitas de inspección y un balance de masa efectuado, se identificó como [A1] el plantear el transporte en seco de subproductos en las áreas de escaldado y eviscerado, lo cual resulta en una reducción del 24% del consumo total. El planteamiento [A2] evaluó la opción de un detergente sintético (alquilbenceno sulfonato lineal), como sustituto del detergente convencional hecho a partir de aceite vegetal.

Los resultados comparativos entre las alternativas [A0][A1][A2] (Figura 2), muestran que la estrategia de reducción de agua [A1]vs[A0], en todas las categorías presento mejoras entre 11% y 28%, para CC y WD respectivamente, para TE solo fue 0,1%. Dichas mejoras fueron por reducciones de insumos químicos para potabilización y consumos de energía. La [A2]vs[A0] presentó una reducción total en la afectación en TE del 99% y del 75% para ME, además de un 11% para CC. No obstante, hubo afectación por agotamiento fósil-FD en -26% porque [A2] emplea derivados del petróleo. En menor proporción hubo afectación a las categorías OD (-3%), FE(-5%) y HT(-3%). En términos de WD no hubo cambios en [A2].

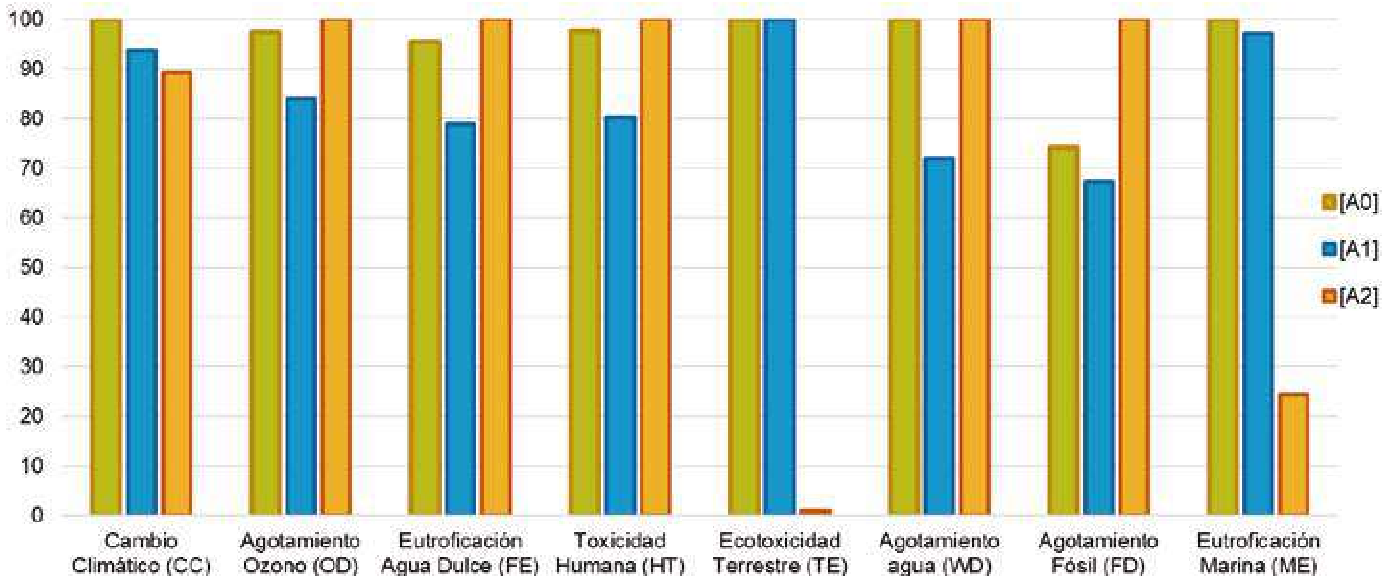


Figura 2. Comparación de las alternativas por categoría de impacto

4| CONCLUSIONES

La línea base de la Planta de Beneficio de Pollo, indico que los detergentes de limpieza y la alta demanda de agua del proceso productivo son aspectos importantes de evaluación. Comparando las alternativas, la minimización del consumo de agua como estrategia de gestión [A1], permitió mejoras en todas las categorías. Así como la evaluación del detergente sintético [A2], favoreció significativamente la reducción en TE y ME, pero generó detrimento en FD. La implementación en conjunto de A1 y A2, da un mejor resultado solo si ambas contribuyen en reducir el impacto. Finalmente, la evaluación de las alternativas considerando su ciclo de vida, permite advertir sobre la magnitud de afectación ambiental que estas puedan o no generar en el ambiente natural, recursos naturales y salud humana y con ello, brindar información para una acertada toma de decisión en la selección de cada alternativa.

| Agradecimientos

Las Plantas de beneficio avícola, FENAVI, Colciencias, PISA y los grupos de investigación ECCA, Logística y Producción de la Universidad del Valle por su apoyo y colaboración.

| Referencias

Bahri, A. (2013). Gestión integrada de aguas urbanas. Global Water Partnership. Comité Técnico (TEC), Tec. Background paper N°16.

de Arruda, S. M., de Souza, G. U., Fonseca, M. X., da Silva, A., & Ulson de Souza, A. A. (2011). Water Reuse and Wastewater Minimization in Chemical Industries Using Differentiated Regeneration of Contaminants. Industrial & Engineering Chemistry Research, 50, 7828-7436.

Gololo, K. V. (2013). Analysis, synthesis and optimization of complex cooling water systems. Doctor of Philosophy. University of Pretoria 167.

Gomes, J. F. S., Mirre, R. C., Delgado, B. E. P. C., Queiroz, E. M., & Pessoa, F. L. P. (2013). Water Sources Diagram in Multiple Contaminant Processes: Maximum Reuse. Industrial & Engineering Chemistry Research, 52(4), 1667-1677.

Koppol, A. P. R., Bagajewicz, M. J., Dericks, B. J., & Savelski, M. J. (2004). On zero water discharge solutions in the process industry. Advances in Environmental Research, 8(2), 151-171.

Martínez-Gómez, J., Burgara-Montero, O., Ponce-Ortega, J., Nápoles-Rivera, F., Serna-González, M., & El-Halwagi, M. M. (2013). On the environmental, economic and safety optimization of distributed treatment systems for industrial effluents discharged to watersheds. Journal of Loss Prevention in the Process Industries, 26(5), 908-923.

Meerholz, A., & Brent, A. (2013). Assessing the sustainability of wastewater treatment technologies in the petrochemical industry. South African Journal of Industrial Engineering August, 24(2), 1-11.

O'Connor, M., Garnier, G., & Batchelor, W. (2013). Life Cycle Assessment of Advanced IndustrialWastewater TreatmentWithin an Urban Environment. Journal of Industrial Ecology.

Statyukha, G., Kvitka, O., Dzhygyrey, I., & Jezowski, J. (2008). A simple sequential approach for designing industrial wastewater treatment networks. Journal of Cleaner Production, 16, 215-224.

ANALYSIS OF THE CARBON FOOTPRINT OF NEW HYDROPOWER PLANTS IN BRAZILIAN LEGAL AMAZON

Marina de A. Azevedo, Juliana F. Picoli, Daniela G. Falco,
Carla Kazue N. Cavaliero, Joaquim E. A. Seabra

University of Campinas – UNICAMP, School of Mechanical Engineering,
Energy Systems Planning program, Campinas, São Paulo, Brazil.
+55 21 986653635,
marina.azevedo@fem.unicamp.br; julianafp@fem.unicamp.br;
falco@fem.unicamp.br; cavaliero@fem.unicamp.br;
jseabra@fem.unicamp.br

ABSTRACT:

Brazil presented among a set of initiatives to cope with climate change a proposal for the expansion of the electricity matrix from renewable energies and a great amount of annual investments for forest recovery in the country. Considering the future national hydroelectricity supply, 90% of the power granted comes from hydropower plants at Amazon region. Compared with power plants that are already performing in the region, the new plants will have an electricity generation similar to 76% of the currently capacity. Among these issues there are conflict interests between the need for energy growth attached to low carbon sources and the hydraulic capacity of Brazilian Amazon, which is linked with the flooding of an area that is naturally an important greenhouse gases (GHG) retainer. The main goal of this paper is to evaluate the carbon footprint from hydropower expansion (EXP) in Brazilian Legal Amazon (BLA). An attributional approach was performed considering as boundaries conditions cradle to gate analysis of the plants in the Brazilian electricity generation and their infrastructure, with the temporal scope of 2013 and 2024. The LCIA was modeled using CML baseline v3.03 from SimaPro®, v.8.3.0 software, with Ecoinvent v3.01 database. Final results show a 4,76E+09 kg CO2eq emission, which represents an 14% raise in carbon footprint.

Keywords:
Legal Amazon, Carbon Footprint, Life Cycle Assessment Hydropower Plants, Environmental Performance.

1 | INTRODUCTION

Climate change and energy security are the main challenges that will shape the future of humanity in the long run. The Brazilian energy matrix is considered a worldwide example of the use of renewable sources. The 2030 Brazilian Energy Plan propounds to triple electricity generation in the next 20 years. The expansion project includes other renewable sources of energy in addition to hydropower, although this continues as the principal one. The large hydroelectric potential available in the South and Southeast regions has been almost all explored by now. Considering that North and Midwest of the country will concentrate the future capacity, Amazon region should cover most of this expansion (TOLMASQUIM, 2007).

This scenario introduces a recent debate: the exploitation of Amazon hydropower potential. In theory the Brazilian hydroelectric generation capacity is 234 GW and in the Amazon this capacity is 77 GW, which means that this region is responsible for 33% of national potential. However, only 38% of this capacity can be explored without significant environmental restrictions, because 80% of these biome is occupied by conservation units (16%), indigenous lands (25%) and / or priority areas for conservation (39%) (TOLMASQUIM, 2007).

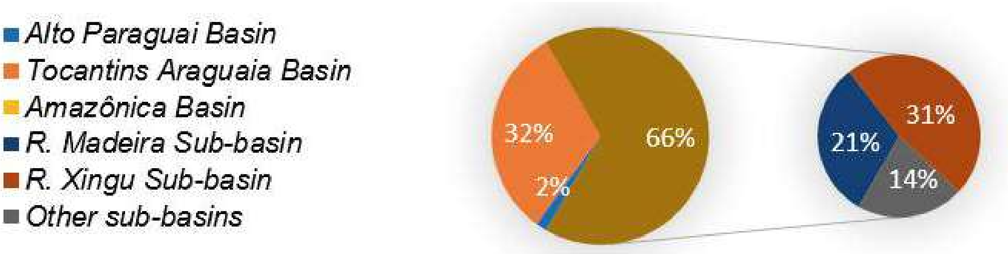
The Brazilian Legal Amazon (BLA) has great potential for hydroelectric generation thanks to the enormous amounts of water resources and the significant topographic falls in the Amazon River's tributaries. However, although the generation of hydroelectricity is almost always considered a clean energy, with low environmental impact, studies (FEARNSIDE, 2015) indicate others important environmental aspects especially when it comes from power plants located in mature native forests. Scientists (NOBRE, 2014) have found that the influence of the forest on the ecosystems is much greater than it was estimated on the past years and also affects other regions of Brazil.

Greenhouse gases (GHG) emissions from hydropower plants in this region are higher than the average recorded in other reservoirs around the world. The increase in the carbon emission rate per year can be up to 7 times higher in the Amazon when compared to temperate regions (BARROS et al, 2011). The emissions can also be relevant considering the flooded area of run-of-river (ROR) and storage power stations (SPS) plants. Flooding of this forest area may cause a number of other environmental and social impacts, such as loss of biodiversity, forest degradation, reduction of fishing potential and removal of traditional populations and indigenous people from their home region.

Therefore, this study aims to evaluate the hydroelectric expansion on the BLA by performing a carbon footprint of new hydropower plants from 2013 to 2024, considering their implementation and operation during this period.

2| METHODOLOGY

The studied scenarios make reference to 2 periods in time, the first one being about the hydropower plants that came to operation until 2013, and the second one being about plants which started working or have been auctioned from 2014 on. There was a total of 21 plants operating in the BLA in 2013, which sum approximately 20GW of power granted. The hydropower expansion (EXP) will occur from 2013 to 2024, with 10 new plants dated by now, that will generate 15GW of power, meaning a 76% of electricity generated so far in the BLA and 90% of total EXP at national territory. For the power granted to the plants, data from the last ten-year energy plan were used: 2014-2024 (EPE, 2016).
The hydropower plants are located at the basins Amazônica, Tocantins-Araguaia and Alto Paraguai, and subdivided into 18 sub-basins. Sub-basins of rivers Madeira, Tocantins and Xingu are the main explored, with 85% of total electricity generation until 2024. Figure 1 presents the power granted percentage distribution through basins regions from total electricity generation in BLA.



Source: Self elaboration, based on ANA (2017).

Considering all information, CO2eq emissions were calculated, as an attributional approach, using the life cycle concept and the technical requirements of the standards ISO 14040 (ABNT, 2009). Hydroelectric dams that have a flooded area of less than 10-9 km2.kWh-1 were considered as ROR plants. In accordance with the criteria, Belo Monte plant will operate as a ROR plants (MMA, 2016), which efficiency is higher than the SPS ones and contributes to a lower carbon footprint.
The reference flow was established based on the annual power granted to the plants (GW) located in the BLA. The average annual amount of the electricity generated (MWh/year) was estimated for each hydropower plant considering the installed capacity, the average capacity factor for Brazilian hydropower plants (about 50%) and the number of hours in the year. CH4 and CO2 emissions related to land use change (from forestry to flooded areas) were adapted considering each hydropower plant flooded area and the emissions factors for Amazon's region, estimated by Santos et al. (2006). The same procedure was take to run-of-river power plants. Table 1 briefly summarizes the adopted process.

The efficiency is related to the electricity generation per flooded area.

Table 1. Process description

Objective	Carbon footprint evaluation (CO2eq emissions) of hydropower expansion in Brazilian Legal Amazon.
Scope	Two productions systems of hydroelectricity: SPS and RPR.
Approach	Attributional LCA
Method	CML V3.03 method.
Category Impact	Global Warming Potential (GWP100)
Software	SimaPro® v.8.3.0
Functional Unit	1 kWh
System Boundary	Cradle to gate, including infrastructure and dLUC.
Data Source	SPS station was based on the dataset "Electricity, high voltage {BR} | electricity production, hydro, reservoir, tropical region | Alloc Def, U" and ROR station on "Electricity, high voltage {RoW} | electricity production, hydro, run-of-river | Alloc Def, U", both from Ecoinvent v3.01 database.

3| RESULTS AND DISCUSSION

The Table 2 shows the electricity generation profiles considered in the study and their emissions, according to the life cycle approach. Just as comparative analysis, the emission factor estimated is adequate to the one calculated using the methodology suggested by IPCC 2013 GWP 100a V1.01, mentioned in the 5th Report.

Table 2. Compilation of the results, including the participation of the storage power station plants (SPS) and the run-of-river plants (ROR).

Period	Power granted (GW)	Electricity generation (GWh)	Total flooded area (km2)	SPS (%)*	ROR (%)*	CO2eq emissions (kg)	Emission factor (kg CO2eq.kWh-1)	
							CML	IPCC
2013	2,02E+01	8,86E+04	9443	97	3	3,40E+10	0,38	0,41
2024	3,55E+01	1,56E+05	10776	66	34	3,87E+10	0,25	0,26
EXP	1,54E+01	6,73E+04	1333	25	75	4,76E+09	0,07	0,08

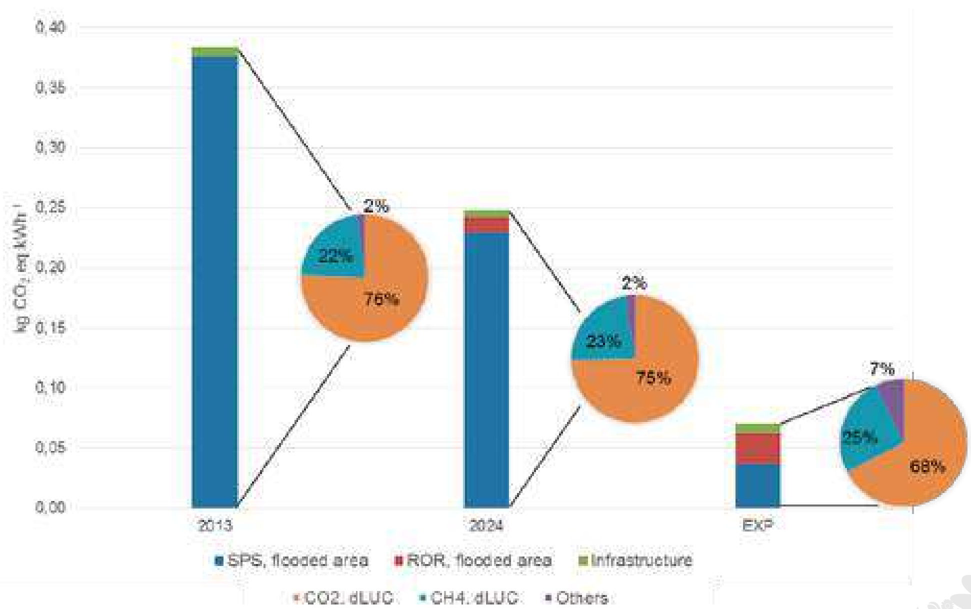
Source: Self elaboration.

*Note: *Related to power granted (GW).*

Therefore the 76% increase in electricity generation by new plants will cause a 14% increase in CO2eq emissions.

Main sources of emissions are related with CO2 and CH4 from dLUC regarding soil carbon losses; biomass losses and decomposition of organic material in the flooded area from accumulation, which explain the great contribution to SPS stations analysis. Processes exits derived from the use of material and energy for the construction, operation and maintenance of the plant accounted for almost 12% of total emissions for EXP period. This contribution is higher than 2013 and 2024 relative results, what conduced to an increase of infrastructure importance in the whole emissions. The contribution of the processes considering CO2eq emission/kWh can be observed in Figure 2.

Figure 2. Contribution of processes and substances.



Source: Self elaboration.

4| CONCLUSIONS

The CO2eq emissions from hydropower plants in BLA in 2013 were related to the large participation of SPS stations, in which dLUC and decomposition of organic matter in the flooded area have a great contribution. Considering that the expansion of hydroelectricity will be performed mainly by ROR plants, which are more efficient than SPS ones, the profile of 2024 BLA generation will change and cause a lower impact to the carbon footprint. In fact, an increase of 76% of electricity generation in the BLA will provide a 14% increase in CO2eq emissions.

Once the results also showed that emission factor (kg CO2eq.kWh-1) reduced during the expansion period caused by the introduction of new ROR stations it would be necessary to review the emission factors of life cycle inventory database for Brazilian hydroelectricity profile process.

Despite the low contribution of infrastructure in the total emission, the relative results showed between 2013 and 2024 indicated that this parameter can became more relevant as the increase of efficiency (reduction of CO2eq emission.km-2) at hydropower stations. Therefore even the analysis that uses this kind of process, as attributional approach should take infrastructure into account.

REFERENCES

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). 2009. NBR ISO 14040: Gestão Ambiental - Avaliação do ciclo de vida - Princípios e estrutura. Brazil.

AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA (ANEEL). 2017. Banco de Informações da Geração – BIG. http://www.aneel.gov.br/aplicacoes/capacidadebrasil/capacidadebrasil.cfm.

AGÊNCIA NACIONAL DE ÁGUAS (ANA). 2017. Sistema Nacional de informações sobre Recursos Hídricos – SNIRH. http://www3.snirh.gov.br/portal/snirh/snirh-1/sistemas

BARROS, N., et al. 2011. Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude. Nature Geoscience, 4(9), 593-596.

EPE – Empresa de Pesquisa Energética. 2016. Plano Decenal de Expansão de Energia 2024.

FEARNSIDE, P. M. 2015. Hidroelétricas na Amazônia: impactos ambientais e sociais na tomada de decisões sobre grandes obras. Manaus: Editora do INPA, 1, 296.

MMA – Ministério de Meio Ambiente. 2016. UHE Belo Monte: perguntas e respostas.http://www.mma.gov.br/estruturas/182/_arquivos/faq_belomonte_182.pdf

NOBRE, A. D. 2014. O futuro climático da Amazônia. Relatório de avaliação científica.http://www.socioambiental.org/sites/blog.socioambiental.org/files/futuro-climatico-daamazonia.pdf.

SANTOS, M. A., et al. 2006. Gross greenhouse gas fluxes from hydro-power reservoir compared to thermo-power plants. Energy Policy. 34, 81-488.

TOLMASQUIM, M. 2007. Plano Nacional de energia 2030. Conselho Nacional de Politica Energetica-CNPE, Brasilia, Brazil.

AWARE PARA SUBZONAS HIDROGRÁFICAS DE COLOMBIA

REGIONALIZING AWARE PER HYDROGRAPHIC SUBZONE OF COLOMBIA

Ing. Maly Puerto López*, MSc. Simon Gmünder**

*** Embajada de Suiza - COSUDE.** Cra 9 No. 74-08, Oficina 806, Bogotá, D. C., Colombia. + 57 1 349 72 30 ext. 801818. E-mail: maly.puerto@eda.admin.ch

**** Quantis Latin America.** Calle 69 # 6 – 20, D. C., Colombia. +57 314 818 22 73. E-mail: simon.gmuender@quantis-intl.com.

ABSTRACT:

Colombia is located in an area of high climate variability, it has three mountain ranges that generate several microclimates and it has development poles with high concentration of economic activities and population, therefore the water availability can vary importantly by sub basin. The AWARE method is a midpoint method that evaluates the Remaining Available Water per area in a watershed, once human and ecosystem needs are covered (WULCA). It is the recommended indicator for water scarcity by the UNEP-SETAC and complies with the ISO14046 water footprint standard. Ultimately, AWARE is available for large water basins that cover Colombia's territory, and is based in a complex model of water balance calibrated with flow data of 724 stations in the world. In order to provide a characterization factor with more detail of smaller scale, we regionalized annual AWARE using data from the National Water Study 2014, which is based on the National web that includes 464 flow stations (IDEAM, 2015). When comparing results, there were significant differences, of 2 magnitude orders more, in the department of Atlántico and close to the coast of Bolívar. There was an increased AWARE, between 1 to 2 units, in hydrographic subzones of Bogotá, Tota lake, and in subzones on departments of Magdalena, Cesar, Huila, Valle del Cauca and Tolima. On the other hand, Guajira's results were between 9 and 13, and the values calculated by WULCA are between 5 and 100. As conclusion, the AWARE calculated from global data available gives a fair approximation to average conditions of the country in most of the territory, but it is convenient to use local data when identifying key water scarcity areas, especially because they usually have large human water consumption associated.

Keywords:

Water scarcity; Water Footprint; AWARE; Colombia; ISO 14046.

RESUMEN:

Colombia está ubicada en una zona de alta variabilidad climática, posee tres cordilleras que generan gran cantidad de microclimas y polos de desarrollo económico y de población concentrados, por lo que la disponibilidad puede variar de manera importante por subcuenca. El método AWARE es el indicador de huella de la escasez de agua recomendado por la UNEP-SETAC, que cumple con la norma ISO 14046 sobre huella de agua. Es un método de punto medio que evalúa el Agua Remanente Disponible por área en una cuenca, una vez cubiertas las necesidades humanas y de los ecosistemas acuáticos (WULCA, 2016). El cálculo actual del AWARE disponible para Colombia utiliza un modelo complejo de balance hídrico y calibrado con datos de 724 estaciones de caudal en el mundo. En este estudio se utilizó el Estudio Nacional del Agua 2014, basado en datos de la red nacional, incluyendo 464 estaciones de caudal (IDEAM, 2015) para regionalizar el cálculo del AWARE anual. Al comparar los resultados, se obtuvieron diferencias significativas, de 2 órdenes de magnitud, en los departamentos de Atlántico y Bolívar, cerca de la costa. El AWARE se incrementó entre 1 y 2 unidades en las áreas del río Bogotá y el lago de tota, y en subzonas de los departamentos de Magdalena, Cesar, Huila, Valle del Cauca y Tolima. Por otro lado, Los resultados para las subzonas en la Guajira fueron 9 y 13, y los valores calculados por Boulay et. al (2016) están entre 5 y 100. En conclusión, el AWARE calculado de datos globales disponibles da una aproximación justa para las condiciones promedio de la mayoría del territorio, pero es conveniente usar datos locales cuando se identifiquen zonas de escasez hídrica clave (1 orden de magnitud) en las áreas del río Bogotá, y en subzonas del Tolima, Valle del Cauca, Quindío, Magdalena y Cesar. Se concluye que el AWARE que parte de datos globales da una aproximación justa pero es recomendable bajar su escala en tanto sea posible para evaluar áreas clave de escasez de agua, especialmente porque son las que usualmente tienen altos consumos humanos de agua asociados.

Palabras clave:

Escasez de Agua; Huella de Agua; AWARE; Colombia; ISO 14046.

1| INTRODUCCIÓN

La huella de agua es una métrica(s) que identifica los impactos potenciales relacionados con el agua (1). El AWARE es el método de impacto recomendado por el grupo de trabajo de la UNEP SETAC, de Análisis de Ciclo de Vida en Agua (WULCA, por sus siglas en inglés), como el indicador de punto medio genérico basado en el estrés hídrico, en el marco establecido para evaluar las rutas de impactos ambientales asociadas al uso de agua según el Análisis de Ciclo de Vida ACV (Boulay et al., 2015). Esta es una recomendación que es el resultado de talleres de expertos y un proceso de consulta con actores interesados de gobierno, academia y empresa (WULCA). El indicador responde a la pregunta: "¿Cuál es el potencial de privar a otro usuario de agua dulce (cualquier ser vivo, sea humano o no) al consumir cierto volumen en una región dada? (Boulay et al., 2015). El indicador está disponible y calculado a nivel de subcuenca y a intervalo mensual, sin embargo en el territorio de Colombia, se basa en la calibración con datos de descarga multianual de 4 estaciones de caudal. En total, se usaron 724 estaciones hidrológicas en el mundo.

Con el fin de obtener un factor de caracterización más refinado, en este estudio se regionaliza el AWARE anual mediante datos disponibles del Estudio Nacional del Agua ENA 2014 (IDEAM, 2015). Gracias a estos, se obtuvo el indicador para las 361 subzonas hidrográficas de las 5 grandes cuencas que se identifican en el territorio: Caribe, Magdalena-Cauca, Orinoco, Pacífico y Amazonas. Los datos del ENA 2014 se basan en 1937 estaciones meteorológicas y 464 estaciones de caudal de la red nacional, correlacionadas con los datos hidrológicos de 8 regiones homogéneas (IDEAM, 2015).

2| METODOLOGÍA

2.1. AWARE

El AWARE es el factor de caracterización para evaluar impacto de punto medio relacionado con el estrés hídrico, en el marco del Análisis de Ciclo de Vida. Su significado físico es "Agua remanente disponible por área en una cuenca, luego de que se cubre la demanda del uso humano y de los ecosistemas acuáticos". Se expresa en con respecto al promedio mundial. Por ejemplo si el WULCA es 10 para cierto lugar, significa que este lugar sufre de 10 veces menos agua disponible por área que el promedio mundial (WULCA). El AWARE está limitado a valores entre 0 y 100. La función matemática para calcularlo es (Boulay et. Al, 2016)

$$AWARE == \frac{AMD_{promedio\_Global}}{\mathrm{AMD}_{cuenca}} \qquad AMD_{promedio\_Global} = 0.0136\,\frac{m^3}{m^2 \cdot mes} \qquad \mathrm{AMD}_{cuenca\ i} = \frac{AD_i - CH_i - QA_i}{Area}$$

Donde:
AD es la cantidad de agua disponible total, calculada como la escorrentía generada en la cuenca durante un mes.
CH es el agua consumida para usos humanos; de agricultura, domésticos e industriales. El agua consumida es el agua evaporada, incorporada a productos y en general, no retornada a la cuenca.
QA es el caudal ambiental, o el requerimiento hídrico de los ecosistemas acuáticos.

2.1. Datos de regionalización

Área de sub cuencas. Se utilizó el estudio de zonificación hidrográfico del país (IDEAM, 2013). Este clasifica el territorio en 361 subzonas hidrográficas de las 5 grandes cuencas: Caribe, Magdalena-Cauca, Orinoco, Pacífico y Amazonas, adicional a las Islas de San Andrés y Providencia.
Disponibilidad de agua. El Estudio Nacional del Agua ENA 2014 utilizó un balance hídrico basado en datos de precipitación de 1937 estaciones meteorológicas, y calibrado con datos de escorrentía superficial promedio de 464 estaciones hidrológicas. El balance hídrico se basa en las ecuaciones de Penmman-Moonteith (FAO, 2006), Turc (1995) y Budykuo, usando 465 estaciones climatológicas.
Consumo de agua humano. El ENA se basa en datos oficiales de entidades nacionales. Así, el consumo de agua para la agricultura se basó en datos del Departamento nacional de Estadística DANE y de gremios como Asocaña, Fedearroz, Fenalce, Fedepala y Fedecafé, ente otros. La información agrícola se obtiene de la encuesta bianual de Evaluaciones Agropecuarias Municipales del Ministerio de Ambiente y Desarrollo Sostenible (EVA), que proporciona datos para el 95% del área cultivada; el consumo se estimó asumiendo que las plantas no sufren de estrés hídrico. El consumo para usos industriales se tomó del "Registro Único Ambiental" RUA, y se complemento con la base de datos de las empresas de agua y saneamiento. El RUA incluía 1674 registros de cerca de 150 mil empresas registradas en el país, pero son los datos oficiales y se espera que correspondan a las empresas más grandes. Para el uso doméstico se baso en la dotación al día por persona para diferentes climas, y se validó con información de la Superintendencia de Servicios Públicos. También se consideraron como consumos las transferencias de una subzona a otra.
Caudal ambiental. El ENA lo calcula según el Decreto 3930 de 2010, basado en datos de estaciones de caudal. Para cuencas de autorregulación alta y poca variabilidad de caudales diarios (con un Índice de Regulación Hídrica IRH > 0,7) se considera como caudal ambiental el valor característico Q85 de la curva de duración (caudal igualado o superado el 85% del tiempo). El IRH se calcula a partir de la curva de duración de caudales diarios, es una relación entre el área bajo el caudal medio y el área bajo toda la curva. Para cuencas con baja autorregulación (IRH < 0,7) se considera como caudal ambiental el valor característico Q75.

2.1. Limitaciones asociadas a los datos de regionalización

Los datos disponibles en el ENA son anuales, pero las fórmulas definidas para el AWARE son mensuales. Se asumió que para el promedio mundial, AMDanual = 12 x AMDmensual. Sin embargo, el AWARE promedio anual se cálcula como el promedio ponderado basado en los consumos de agua mensuales. No se esperaría una diferencia muy grande entre el promedio simple y el promedio ponderado cuando se consideran los consumos globales.

Este estudio evalúa la escorrentía de la subcuenca, por lo tanto no incluye como parte de la oferta el flujo de agua del río principal si este es un divisor entre SZH, o si solo pasa por su perímetro. Sin embargo, algunas actividades humanas dentro de la zona pueden estar usando los causes de estas divisoras. Se espera sin embargo que los principales consumos dependan de la escorrentía generada directamente en la zona evaluada.

3| RESULTADOS Y DISCUSIÓN

En la figura 1 se presentan los resultados de la regionalización obtenida. En la mayoría del territorio el AWARE regionalizado con datos del ENA es similar al AWARE calculado por Boulay et al. (2016). El AWARE regionalizado con datos locales se incrementa levemente del rango de 0-0.1 al rango de 0.01-0.4 en la mayor parte del territorio.

Sin embargo, para algunas subzonas hidrográficas se obtuvieron diferencias significativas, de hasta 2 órdenes de magnitud. Es el caso de los departamentos de Atlántico y el norte de Bolívar, cerca de la costa. El AWARE se incrementó entre 1 y 2 unidades en las áreas del río Bogotá y el lago de Tota, y en subzonas de los departamentos de Magdalena, Cesar, Huila, Valle del Cauca y Tolima. Por otro lado, Los resultados para las subzonas en la Guajira fueron 9 y 13, y los valores calculados por Boulay et. al 2016 están entre 5 y 100.

En la tabla 1 se presentan algunas de las zonas en las que los resultados de este estudio difieren con respecto al valor calculado por Boulay et al. (2016)

Tabla 1. *Resultados de AWARE regionalizado comparados para algunas subzonas hidrográficas*

Subzona(s) hidrográfica(s)	AWARE (Boulay et al 2016)	AWARE regionalizado con datos ENA 2014
Arroyos directos al caribe, margen derecho del canal del dique (Atlántico y norte de Bolívar)	3 y 0	100
Ariguaní, Chimicuica, Plato (Magdalena)	0	1.5 – 1.8
Medio Cesar	0	2.2
Directos al magdalena, Río Yaguará y Iquira, Río Bache, Río Fortalecillas, Río Neiva	0	0.5 – 1.5
Medicanoa y Piedras, Guachal, Ríos Lilí, Melendez y Canaveralejo, Río Paila y Río Las cañas (Valle del Cauca)	0	1.0-1.7
Río Sumapaz	0	0.6
Río Bogotá	0	2.2
Río Chicamocha	0	0.7
Lago de Tota	0	1.3
Río Porce (incluye Medellín)	0	0.5
Ay.Sharimahana, Río Carraipia - Paraguachon, Directos al Golfo Maracaibo (Guajira)	5-100	9-13
Guáitara, Juananbú, Chingual (Nariño)	0	0.5
Rio Tapias y otros directos al Cauca (Quindío)	0	0.5
Isla de San Andrés	No reporta	0.9

4| CONCLUSIONES Y RECOMENDACIONES

Si bien para la mayor parte del territorio el AWARE no varío significativamente con respecto a Boulay et al. (2016), es notable que haya áreas de alto desarrollo con un AWARE superior a 1, que según datos globales tienen un estrés de 0. La mayoría de estas zonas se caracterizan por grandes ciudades y alta producción agropecuaria e industrial, como es el caso de las que se localizan en Atlántico, Valle del Cauca y Bogotá. Para el territorio Colombia, esto también podría asociarse al cambio en la oferta natural de agua aún a pequeña escala. Esta se relaciona con una alta variabilidad climática a lo largo de su territorio que se asocia, entre otros, a su ubicación en un área tropical y montañosa que genera microclimas.

En este sentido, se concluye que el AWARE que parte de datos globales da valores similares para la mayoría del territorio pero es recomendable bajar su escala en tanto sea posible, sobre todo para áreas de alta concentración de usos humanos del agua disponible.

AWARE de regionalización con datos globales (Boulay et. al 2016)

AWARE con datos de ENA 2014

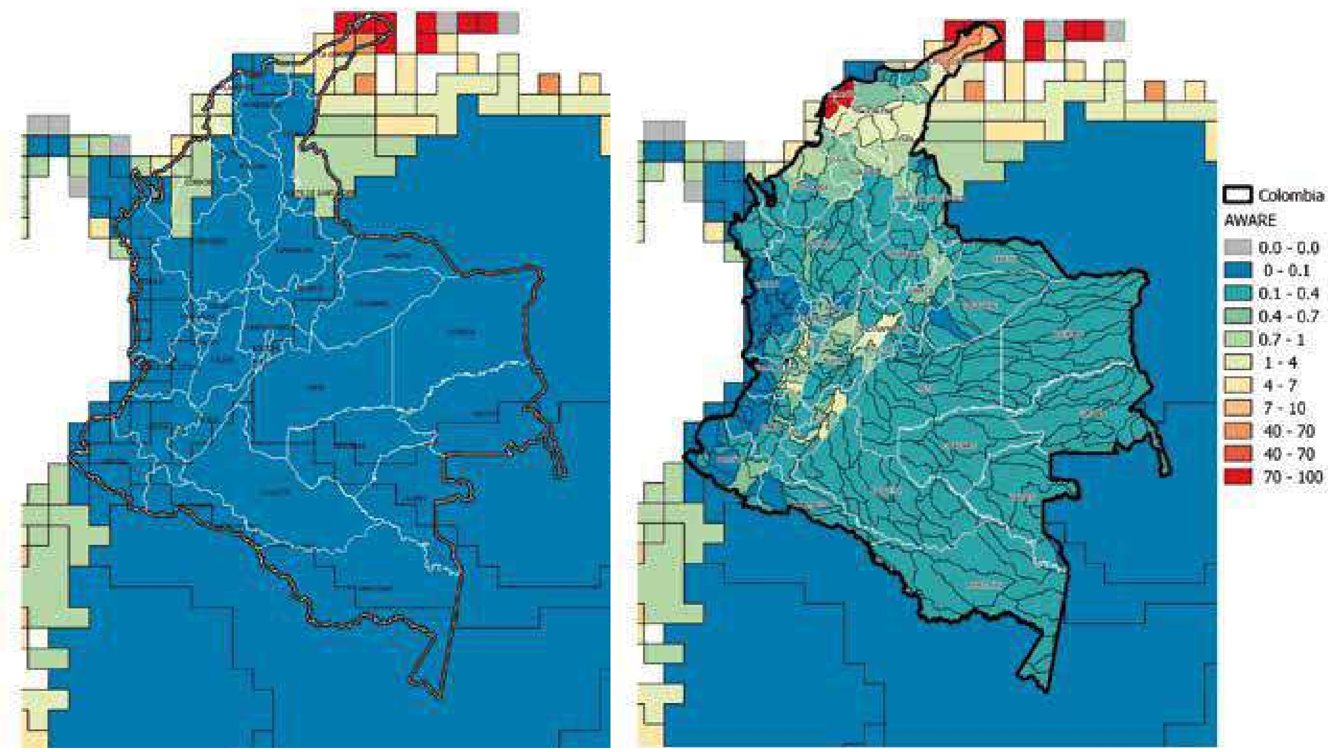


Figura 1. *Regionalización del AWARE promedio anual (uso no especificado) por subzona hidrográfica en ENA*

Finalmente, para lograr un resultado más exacto, debería calcularse el AWARE mensual y evaluar el anual basado en el promedio ponderado en los consumos humanos. Sin embargo, estimar los datos de disponibilidad de agua mensual por subzona hidrográfica representa un desafío porque cobraría importancia la evaluación del almacenamiento en cada zona, para la cual la información es limitada. A pesar de esto, se puede llegar a una aproximación de que tan grande podría ser la desviación mensual del AWARE con respecto a su promedio anual usando los datos disponibles sobre escorrentía mensual, lo que se sugiere para un futuro esfuerzo.

Reconocimientos

Los autores expresan su agradecimiento a:
La subdirección de Hidrología del Instituto Nacional de Hidrología, Meteorología y Estudios Ambientales IDEAM, quien facilitó la información utilizada, que corresponde a los datos del Estudio Nacional del Agua 2014.
Diego Arévalo Uribe, quien contribuyó en la interpretación de los datos disponibles.
Diana Rojas, de la Embajada Suiza - COSUDE, quien contribuyó a enmarcar este esfuerzo en el interés institucional de mejorar los indicadores asociados a la huella de agua para su uso público.

Referencias

Boulay A., Bare J., Benini L., Berger M., Manzardo A., Margni M., Motoshita M., Núñez M., Lathuillière M., Pastor A., Ridoutt B., Worbe S., Pfister S. 2016. The WULCA consensus for water scarcity footprints : Assessing impacts of water consumption based on the available water remaining (AWARE). Presentado para publicación. Capa de google earth descargable de http://www.wulca-waterlca.org/Documents/AWARE_v1_2April_7-th.kmz

Boulay A. Bare J. De Camillis C. Döll P. Gassert F., Gerten D., Humbert S., Inaba A., Itsubo N., Yan L., Margni M., Motoshita M., Núñez M., Pastor A., Ridoutt B., Schencker U., Shirakawa N., Vionnet S., Worbe S., Yoshikawa S., Pfister S. 2015. Consensus building on the development of a stress-based indicator for LCA-based impact assessment of water consumption: outcome of the expert workshops. Int. J. L.. C. Assess. 20(5) 577-583. En: http://link.springer.com/article/10.1007%2Fs11367-015-0869-8

IDEAM, Instituto de Hidrología, Meteorología y Estudios Ambientales. 2013. Zonificación y codificación de cuencas hidrgráficas e hidrogelógicas. Bogotá : s.n., 2013.

IDEAM, Instituto de Hidrología, Meteorología y Estudios Ambientales. 2015. Estudio Nacional del Agua 2014.

ISO. 2014. ISO 14046 : Water footprint, guidelines and requirements. 2014.

WULCA. Water Use in Life Cycle Assessment. The AWARE method. [En línea] http://www.wulca-waterlca.org/project.html.

BUSCANDO LA SUSTENTABILIDAD DEL USO DE AGUA EN EL ÁREA METROPOLITANA DE MENDOZA, ARGENTINA

PhD. Bárbara M Civit*,, PhD. Jimena Gómez Piovano*and Ing. Noelia R Ortiz***

* CONICET Mendoza, INAHE. Av Ruiz Leal s/n. (5500) Mendoza, Argentina. +54 261 5244310
**UTN FRM, Grupo CLIOPE. Rodriguez 273 (5500) Mendoza, Argentina. +54 261 5244693
bcivit@frm.utn.edu.ar; jpiovano@mendoza-conicet.gob.ar; nortiz@mendoza-conicet.gob.ar

RESUMEN:

El Área Metropolitana de Mendoza (AMM) se ubica en una región semiárida donde el agua es un recurso escaso y su disponibilidad determina las posibilidades de desarrollo económico y social. Para que ese desarrollo sea sustentable, ante el aumento de población y de la demanda habitacional, debe proponerse un modelo de crecimiento urbano que contemple el menor uso de recursos. Este trabajo tiene como objetivo establecer patrones de consumo de agua en el AMM y calcular los volúmenes de agua asociados a las distintas tipologías de vivienda que predominan en el sector, utilizando en primera instancia la huella hídrica como indicador. Mediante encuestas se determinó el consumo de agua directo e indirecto, estableciendo patrones y hábitos de consumo por tipo de vivienda. Se consideró como unidad de análisis un metro cuadrado de terreno habitado. Resultados preliminares demuestran que los mayores consumos de agua directa están asociados a la higiene personal, el lavado de vestimenta y blanco independientemente de la tipología edilicia y del estrato social de sus ocupantes. En las viviendas con jardín, el riego ocupa la mayor cantidad de agua. El agua indirecta está asociada en gran medida al consumo de alimentos y vestimenta, y es relativamente independiente del modelo de vivienda, pero sí de las condiciones socioeconómicas. Estos hallazgos confirman que, en términos generales, el uso de agua depende en gran medida de las elecciones de los consumidores. Asimismo, contribuyen a planificar cómo podría crecer la mancha urbana atendiendo la disponibilidad de los recursos hídricos y su uso.

Palabras clave:

Uso de agua; ordenación de territorio; indicadores.

1 | INTRODUCCIÓN

El agua es una variable esencial en las 3 dimensiones del desarrollo urbano sostenible. Globalmente, las últimas décadas han registrado aumentos del consumo de los recursos hídricos que no está supeditado al crecimiento poblacional sino a los cambios en los patrones de uso (Almirón, 2014). En los años 40s se usaban 400m3 de agua por persona al año mientras que actualmente se requieren 800m3 (Olcese, 2000). Del mismo modo, la contaminación del recurso ha crecido, siendo responsables todos los sectores económicos. En el Área Metropolitana de Mendoza (AMM) situada en la región árida del centro oeste argentino, el agua es el recurso escaso y su disponibilidad determina las posibilidades de desarrollo económico y social. Con una superficie de 20.600 ha constituye el principal asentamiento urbano de la provincia y concentra a más del 90% de la población. En los últimos años la trama urbana ha incrementado su superficie con un ritmo anual del 4,5%, lo que significó un crecimiento del 135% entre los años 1983 y 2010. A la vez, el consumo de anual de agua se acrecienta en 1, 6% mientras que el crecimiento poblacional es del 1,2%.
Lo expuesto motoriza la búsqueda de propuestas de uso sustentable de agua en las ciudades modernas que permitan el desarrollo respetando los límites de los recursos y el ambiente natural y construido. Para ello, el primer paso es contabilizar los volúmenes de agua asociados a las distintas actividades residenciales y determinar un patrón de consumo de agua residencial por zona y tipología de vivienda, que podrá usarse como datos de entrada en un modelo para relacionar la oferta hídrica con la ocupación urbana en el AMM ofreciendo una herramienta de soporte para la gestión del recurso hídrico.

2 | MATERIALES Y MÉTODOS

La metodología de la huella hídrica, permite cuantificar el consumo directo e indirecto de agua por parte de un consumidor o un productor, concepto que fue introducido por primera vez en 2002 (Hoekstra, 2003) y luego Hoekstra y Chapagain en 2007 definieron y desarrollaron una herramienta de cálculo. Esta huella fue concebida como una herramienta analítica y geográficamente explícita, para abordar cuestiones relacionadas con políticas de seguridad hídrica y uso sostenible del agua, relacionando la ubicación (y la extensión) donde se produce el uso con el consumo que realizan las personas (Hoekstra y col, 2011). Este trabajo pretende ser una antesala a la cuantificación de la huella hídrica de la provincia de Mendoza, y cuantifica el agua directa -aquella que interviene directamente en las actividades domésticas, como bañarse, beber, lavar la ropa y demás-, y la indirecta, asociada a la producción de los bienes que un individuo consume. Este estudio considera solamente la que está asociada a los alimentos y bebidas consumidos por año según el tipo de dieta en el AMM porque se piensa que puede ser el factor que más influencia tenga en el volumen total. La unidad de análisis se estableció en 1m2 de terreno habitado porque la función principal del AMM es dar residencia a la población. Se busca establecer, si existe, la relación entre tipología urbana y consumo de agua según patrones y hábitos de consumo.

Área de estudio.

Se consideró el Área Metropolitana de Mendoza y su mancha urbana, ubicada en el oasis irrigado Norte de la provincia de Mendoza.
En ella, habitan 908.646 personas distribuidas de manera no uniforme en los 6 departamentos que la componen, y se desarrollan todas las actividades económicas, pero fundamentalmente la residencia y la administración pública (incluyendo salud, justicia y educación de todos los niveles educativos).

Uso y Consumo de agua.

Con la finalidad de determinar los volúmenes de agua asociados a los distintos usos residenciales, en 2015, se diseñó una encuesta de 50 preguntas sobre características del encuestado y de la vivienda, hábitos de uso de agua y por último, sus hábitos alimentarios, que se distribuyó por correo electrónico a diversas instituciones públicas y privadas. También se compartió en diversas redes sociales y se completó el número de encuestas para cumplir con el tamaño de muestra con entrevistas personales en cada departamento considerado en el estudio . La información recopilada de este modo, se trabajó en planillas de cálculo, convirtiéndola en volúmenes de agua según bibliografía (Hoekstra, A.Y. and Chapagain, 2008), factores de la Organización Mundial de la Salud (Howard and Bertram, 2003) y se ajustaron con mediciones de caudal llevadas a cabo en las viviendas de los autores.

La encuesta, que continúa disponible on-line en el sitio http://www.mendoza-conicet.gob.ar/encuestanueva/index.php/survey/index/sid/899315/lang/es

3 | RESULTADOS Y DISCUSIÓN

Hasta el momento, fueron respondidas 467 encuestas, de las cuales 363 se aceptaron como “buenas” porque se había completado en más del 95% con una respuesta válida (no se había dejado el casillero en blanco).

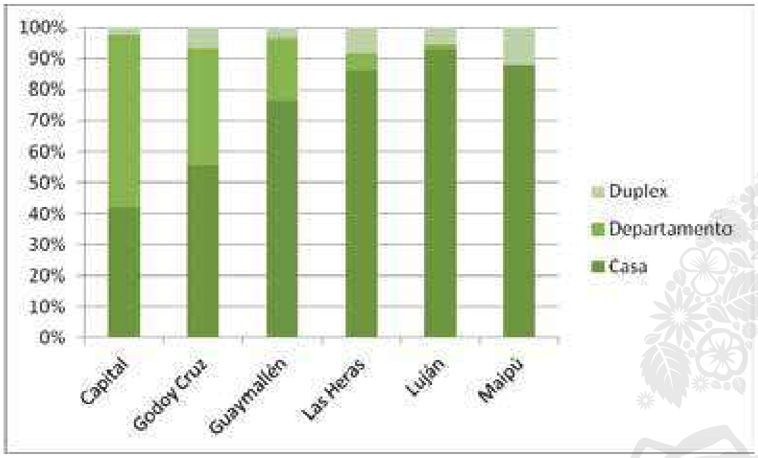
Caracterización de los encuestados.

El mayor número de respuestas provino del departamento de Godoy Cruz, seguido por Capital y luego por Guaymallén. El 63% de las encuestas fue respondido por mujeres, el 36% por hombres, mientras que el 1% del total no especificó sexo. El 76% de los encuestados tiene entre 33 y 45 años, seguido en segundo lugar por la franja etaria de 46 a 65 años con el 16%, mientras que un pequeño porcentaje se sitúa en los extremos de edad, menores de 18 y mayores de 66 años. La mayoría de ellos, alcanzó un nivel terciario o universitario, con el 58%, y el 37% obtuvo un título de posgrado, mientras que un 5% consiguió sólo completar el nivel secundario de educación. El 100% completó el nivel primario de educación.

Uso y consumo directo de agua.

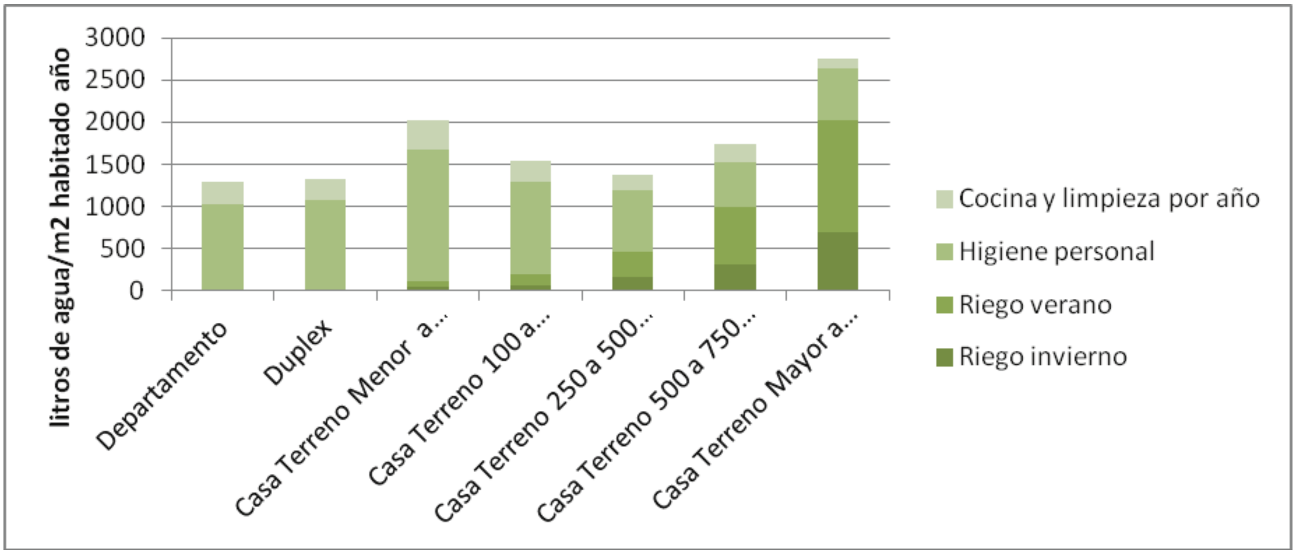
Para analizar la relación existente entre los patrones de consumo de los encuestados con las características de la vivienda se identificó en primera instancia, el tipo de vivienda distinguiendo ente Duplex, Departamento y Casa, y la proporción de cada uno de ellos por departamento (Figura 1). A su vez, el 48% habita vivienda de barrio con o sin mejoras; el 35%, casa de zona residencial en zona urbana y el 17% en casa en zona residencial en las afueras de la ciudad.

Figura 1. Tipo de vivienda por departamento.



En términos generales, los terrenos de las viviendas unifamiliares tienen entre 100 – 250 m2 y entre 250 – 500 m2. Una menor proporción con terrenos mayores a 750 m2. Estos últimos, se ubican principalmente en los departamentos de Luján de Cuyo y Maipú, histórica zona agrícola, hacia donde avanza el crecimiento de la zona urbana ocasionando un cambio en el uso del suelo, del agua y de la biodiversidad. Cuando se analiza el uso directo de agua, por departamento, tipología de vivienda y tamaño de lote, se verifica que el agua necesaria para aseo personal, limpieza y preparación de alimentos se mantiene prácticamente constante e independiente del sitio, del tipo de vivienda y del tamaño del lote donde se emplaza la vivienda (Figura 2). Sin embargo, el agua destinada a riego de exteriores y jardines, está directamente influenciada por el sitio, la extensión del terreno y por ende, por el tipo de vivienda. Cuando los lotes superan los 500 m2, se ocupa casi 7 veces más agua para riego que para las otras actividades de interiores.

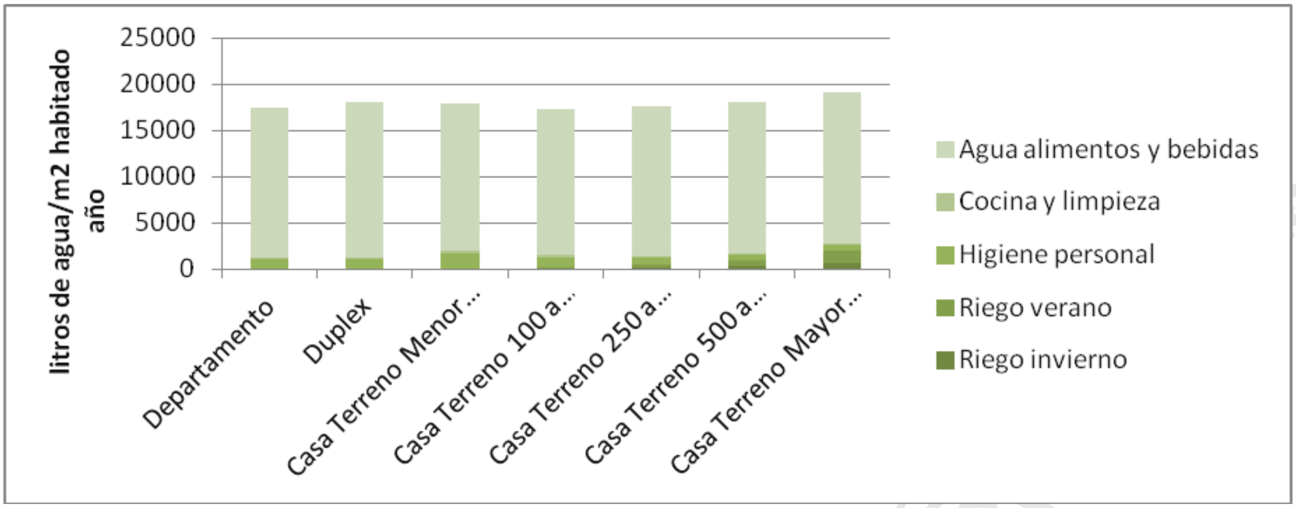
Figura 2. Distribución de uso de agua por actividad doméstica para cada tipología de vivienda y tamaño de lote, en litros/m2 habitado/año.



Consumo indirecto de agua.

El consumo de agua indirecto en un individuo se relaciona con el agua necesaria para producir bienes y servicios que consume no solamente dentro de la planta de producción, sino a lo largo de toda la cadena de suministro. Como primer intento por cuantificar el volumen de agua indirecta, se consultó sobre la frecuencia de ingesta de alimentos, agrupándolos por momento del día en que se consumen. Para ello, se siguió el mismo esquema del calculador de huellas desarrollado en el plano nacional, YUPI® (Arena et al, 2016). Del total de encuestas tomadas como válidas, el 94% tiene una dieta omnívora, mientras que sólo el 6% es lácteo vegetariano. Cuando se analizó el tipo de alimentación y el tamaño de lote, la ubicación y el tipo de vivienda, no se encontró una relación directa en ninguno de los casos, pero se verificó que el agua asociada a la alimentación y bebida (indirecta) es la que ocupa la porción más significativa en el total de agua consumida por m2 habitado por año (Figura 3), hipótesis inicial.

Figura 3. Distribución de uso de agua directa e indirecta para cada tipología de vivienda y tamaño de lote, en litros/m2 habitado/año.



4| CONCLUSIONES Y RECOMENDACIONES

Se obtuvo una primera imagen de la situación de uso de agua en el AMM, por departamento, tipología de vivienda y características de sus ocupantes. Si bien a partir de estos resultados no se puede establecer un patrón que correlacione completamente los hábitos de consumo con la tipología de vivienda porque se debería incorporar variables económicas y sociales (como el nivel de ingreso, poder adquisitivo, nivel de vida, gustos, preferencias, otras), que acompañen las elecciones de los individuos a la hora de elegir dónde vivir y qué consumir, estos hallazgos preliminares son muy útiles para poder ir delineando conclusiones parciales y han permitido inferir que no se puede pensar en desarrollo urbano sostenible sin una modificación en los usos del agua. Este es un primer paso, que da lugar a seguir profundizando el análisis de datos, la búsqueda de posibilidades de expansión urbana y la transferencia de los resultados a los tomadores de decisión.

Bibliografia

Almirón, E. 2014. El agua como elemento vital en el desarrollo del hombre. Recuperado en http://www.observatoriomercosur.org.uy/libro/el_agua_como_elemento_vital_en_el_desarrollo_del_hombre_17.php.

Arena, AP; Piastrellini, R, Barón G and Civit, B (2016) YUPI®, a regional footprint calculator. International Journal of Life Cycle Assessment; Lugar: HEIDELBERG; Año: 2016 p. 1 - 11

Guzmán Soria, E.; García Salazar, J.; Rebollar Rebollar, S.; Hernández Martínez, J. 2011 Determinantes del consumo de agua por los sectores urbano e industrial en Guanajuato, México. Análisis Económico (63) 26, 199-213.

Hoekstra, A.Y. 2003 (ed) Virtual water trade: Proceedings of the International Expert Meeting on Virtual Water Trade, IHE Delft, the Netherlands. 06.133

Hoekstra, A.Y. and Chapagain, A.K. 2008. Globalization of water: Sharing the planet's freshwater resources, Blackwell Publishing, Oxford, UK.

Hoekstra, AY and Chapagain, AK .2007 Water footprints of nations: Water use by people as a function of their consumption pattern. Water Resour Manage (2007) 21:35–48, DOI 10.1007/s11269-006-9039-x

Hoekstra,A, Chapagain, A, Aldaya, M y Mekonnen, M. 2011 The Water Footprint Assessment Manual. Setting the Global Standard. Earthscan, London • Washington, DC

Howard and Bertram. 2003 Domestic Water Quantity, Service, Level and Health. World Health Organization. http://www.who.int/water_sanitation_health/diseases/WSH03.02.pdf?ua=1

Olcese, O.; 2000. Importancia del agua en el desarrollo Social y económico. En Paulet Iturri, M.; Prieto Celi, M.; Rojas, G.;(Ed.) La gestión del agua. La Autogestión Administrativa y Financiera. Experiencia Nacional e Internacional. Perú.

EVALUACIÓN DEL POTENCIAL DE REDUCCIÓN DE LA HUELLA DE CARBONO EN MATERIALES DE CONSTRUCCIÓN ALTERNATIVOS MEDIANTE EL ANÁLISIS DE CICLO DE VIDA

EVALUATION ON THE POTENTIAL FOR CARBON FOOTPRINT REDUCTION OF CONSTRUCTION MATERIALS THROUGHT THE LIFE CYCLE ASSESSMENT

MSc. José Alberto Sierra Martínez*, Dr. Marcos Algara Siller*, Dr. Gerardo Javier Arista González y Dr. Jorge Aguillón Robles****

* UASLP, Facultad de Ingeniería, Ingeniería Ambiental. Manuel Nava #8, Col. Zona Universitaria Poniente, San Luis Potosí, San Luis Potosí, México. +52(444) 826-2330. jsierrahernandez@yahoo.com.mx, marcos.algara@uaslp.mx

** UASLP, Facultad del Hábitat, Instituto de Investigación y Estudios de Posgrado. Niño Artillero #150, Col. Zona Universitaria Poniente, San Luis Potosí, San Luis Potosí, México. +52(444) 826-2330. garista@fh.uaslp.mx, aguillon@fh.uaslp.mx

bcivit@frm.utn.edu.ar; jpiovano@mendoza-conicet.gob.ar; nortiz@mendoza-conicet.gob.ar

RESUMEN:

En diciembre de 2015 México ratificó, ante la Conferencia de las Partes (COP 21) de la Convención Marco de Naciones Unidas sobre el Cambio Climático en Francia, el compromiso para la reducción de gases de efecto invernadero (GEI) en un 22% para el año 2030 de manera no condicionada. Para este fin el Instituto Nacional de Ecología y Cambio Climático ha puesto en marcha la Política Nacional de Cambio Climático. En el presente trabajo se examina la propuesta de utilizar el Análisis de Ciclo de Vida para cuantificar las emisiones de dióxido de carbono equivalente en la industria de la construcción. De manera específica, se basa en el desarrollo de bloques de suelo compactado y estabilizado para uso urbano que hemos realizado en años recientes en el grupo de investigación. El bloque de suelo compactado ha sido diseñado para cumplir con las normas de construcción en cuanto a resistencia por compresión, como mínimo necesario para su uso estructural en edificaciones de 1 a 3 niveles. El resultado al comparar sus emisiones con el block de concreto, que es el material más utilizado en el tipo de vivienda estudiado, es significativo y alcanza una proporción de 12 veces la emisión de CO_2 equivalente a favor del material alternativo. Este resultado ayuda a fundamentar el beneficio de los materiales alternativos de construcción para posicionarlos en el mercado de vivienda social.

Palabras clave:

huella de carbono; materiales alternativos; COP21

ABSTRACT:

On December 2015 Mexico ratified, during the Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change in France, the compromise to reduce Green House Gases (GHG) up to 22% by the year 2030. In order to reach this goal, the National Institute for Ecology and Climate Change (Instituto Nacional de Ecología y Cambio Climático) started the National Policy on Climate Change (Política Nacional de Cambio Climático). This work examines the use of Life Cycle Assessment to quantify equivalent carbon dioxide emissions from the construction industry. Specifically, the work is based from a project on compacted and stabilized soil blocks for urban use that our research group has developed. The block has been designed to meet construction codes for compression strength, as a minimum requirement for its use as a structural element on buildings from 1 to 3 floors. The comparison with common concrete block, the most used on social housing in Mexico, resulted in a significant 12 times CO_2 eq. emissions, in favor to the alternative material. This result would help to justify the benefits from alternate construction materials for commercial use.

Keywords:

carbon footprint; alternative construction materials; COP21

1| ANTECEDENTES

El ACV, Análisis de Ciclo de Vida, estudia los aspectos ambientales y los impactos potenciales a lo largo del ciclo de vida de un producto o de un proceso productivo. El ciclo de vida de un producto considera todos los elementos para producir un producto desde su origen (materia prima) hasta su disposición final (residuo). Se toman en cuenta todas las fases intermedias como transporte y preparación de materias primas, manufactura, transporte, distribución y uso, y en ocasiones incluso se considera su probable reutilización como otra materia prima. (ISO 14040, 2006).
Los tipos de ACV se clasifican en Tipo 1 de la cuna a la puerta: es el ciclo de vida que abarca la extracción y hasta la generación del producto, justo antes de que se inicie sus etapas de uso y mantenimiento; Tipo 2 de la cuna a la tumba: que abarca desde la extracción del producto hasta su disposición final; y Tipo 3 de la cuna a la cuna: desde la extracción hasta la reutilización o reciclaje ya sea en el mismo sistema del producto o en otro diferente.

2| INICIATIVAS DE REDUCCIÓN E INDICADORES

El COP 21 (Conferencia de las Partes, Siglo XXI) es un instrumento de alcance mundial para enfrentar de manera global el cambio climático, el cual busca que por lo menos 195 países reorienten su desarrollo hacia un mundo más sostenible, con menores emisiones y con capacidad de adaptación a un clima más extremo.
México, así como otros países, ha publicado sus compromisos independientes para la reducción de emisiones contaminantes hacia el año 2030. De acuerdo con un documento de la Secretaría de Medio Ambiente y Recursos Naturales (Semarnat), éstos son algunos de los objetivos que se perseguirán a nivel nacional en materia ambiental: 50% de reducción de emisiones contaminantes, comparada con las generadas en 2000; 25% menos de emisiones de compuestos de efectos invernadero. Según la dependencia, se disminuirán en 22% los GEI, gases de efecto invernadero y en 51% el carbono negro para alcanzar la meta, y además 43 de cada 100 fuentes de energía serán limpias, es decir, que provendrán de fuentes renovables, en cogeneración con gas natural y plantas termoeléctricas con captura de dióxido de carbono. Se espera un avance de 35% para 2024 y además, el país se comprometió a promover el uso doméstico de calentadores y celdas solares.
"El sector de la construcción moviliza el 10% de toda la economía mundial y consume cada año un 40% de la energía producida en todo el mundo" (Lippiatt, 1998).
"Anualmente el 24% del gas natural y el 35% de la electricidad consumida en los Estados Unidos de Norteamérica se usa para iluminar, acondicionar ambientes y poner en funcionamiento los edificios. Como consecuencia de estos consumos, se emiten cerca de 1.3 millones de toneladas anuales de GEI's (Blanchard et al, 1998). Estudios efectuados en Reino Unido, Francia y España revelan que el consumo energetico asociado a la construcción se distribuye de la siguiente manera: el 48% para el consumo directo por uso (electricidad, gas, etc.), el 33% para transporte y el 19% para la construcción y mantenimiento de los edificios (Itec, 2000).
La cantidad de residuos de la construcción y demolición generados en el conjunto de países de la Unión Europea, supera los 180 millones de toneladas al año, hecho que representa 480 kg por persona al año. De aquí solamente el 28% de estos residuos son reutilizados o reciclados, el restante (72%) se envía a vertederos (Symonds, 1999).
Las emisiones de CO2 fueron de 493,450.6 Gg en 2010, con una contribución de 65.9% al total del inventario y con un incremento de 23.6% con respecto a 1990. Las emisiones de CO2 en el país provienen principalmente de la quema de combustibles fósiles y procesos industriales. Los sectores con mayor contribución porcentual de emisiones de CO2 son: el transporte con 31.1%, la generación eléctrica con 23.3%, la manufactura y construcción con 11.4%, el consumo propio de la industria energética con 9.6%, la conversión de bosques y pastizales con 9.2% y otros usos (comercial, residencial y agropecuario) con 6.7%.

3| METODOLOGÍA

En primer término se revisaron conceptos básicos de las normas ISO 14040:2006 Environmental management – LCA – Principles and framework e ISO14044:2006 Environment management–LCA–Requirements and guidelines. Segundo, se definieron para el análisis comparativo, el material convencional (block de cemento) y el alterno (BTC, block de tierra comprimida), para que mediante la metodología ACV se identifiquen los impactos asociados a ambos materiales y, establecer alternativas sustentables asociadas al uso de insumos para la industria de la construcción menos nocivos con el medio ambiente.
Para homogenizar los resultados asociados a cada producto, se estableció como unidad funcional 1 m2 de muro con sus juntas y acabados y se realizaron los balances de materia y energía correspondientes a cada producto. Ver tablas 1 y 2.
Para obtener datos de inventario de 1m2 de muro de BTC y del block de cemento, se realizaron visitas de campo a bancos de arcilla y bloqueras ubicados en la Cd. de S.L.P. y se efectuaron pruebas de calidad en laboratorio, posteriormente se recopilaron inventarios sobre procesos de fabricación de ambos productos, cantidades de materia prima, energía, asociada, transportes y datos de sus correspondientes morteros y recubrimientos.
De acuerdo con la norma ISO 14040 (NMX-SAA-14040-IMNC-2008) , los datos seleccionados para un ACV deben ser recolectados desde los sitios de producción relacionados con los procesos unitarios dentro de los límites del sistema, o bien, deben ser obtenidos y calculados mediante otras fuentes.
Los datos de producción de BTC y block de cemento fueron obtenidos en bloqueras locales y a partir de producción experimental de BTC realizada en la UASLP. El proceso de fabricación de estos materiales fue ajustado con datos obtenidos mediante fichas técnicas de los lugares de producción y otras bases de datos. Ver tabla 3.
Los datos de inventario sobre la extracción de materias primas así como el transporte de bancos a centros de producción y otros procesos relacionados, se obtuvieron de diversas bases de datos mexicanas. Así mismo, los datos sobre consumos de energía eléctrica se obtuvieron directamente en los centros de producción del block y del BTC con datos del laboratorio. Ver tabla 3.
Posteriormente se llevó a cabo el análisis comparativo de ciclo de vida entre ambos productos utilizando el software GaBi y, se seleccionaron cuáles serían los impactos relevantes para la investigación. Ver fig. 1 y 2. Finalmente se realizó la interpretación de los resultados obtenidos.

Tabla 1. Características de los productos analizados

Material	Tizón (cm)	Soga (cm)	Grueso (cm)	Tipo de juntas	Tipo recubrimiento
Block de cemento	12	40	20	Mortero Cal cemento, arena y agua	Mortero: Cal, cemento arena y agua
BTC	15	30	12	Mortero Cal cemento, arena y agua	Mortero Cal cemento, arena y agua

Tabla 2. Flujos de referencia de componentes de los muros

Muro	Elemento base (pza)	Juntas (m^3)	Recubrimiento (m^3)
Block de cemento	11.90	0.135	0.0168
BTC	24.81	0.0577	0.0314

Tabla 3. Inventario de materias primas de los productos analizados

Material	Unidad	Block de cemento	BTC
Áridos	kg	200.55	293.78
Agua	l	33.43	40.78
Energía	MJ	79.80	10.27
Transporte	km	137.51	115.70
Emisiones	g	35.35	18.98

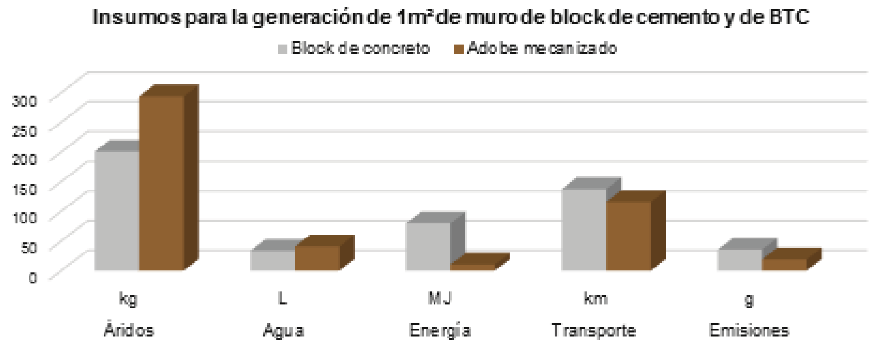


Figura 1. Comparación de insumos del block de concreto y el adobe mecanizado.

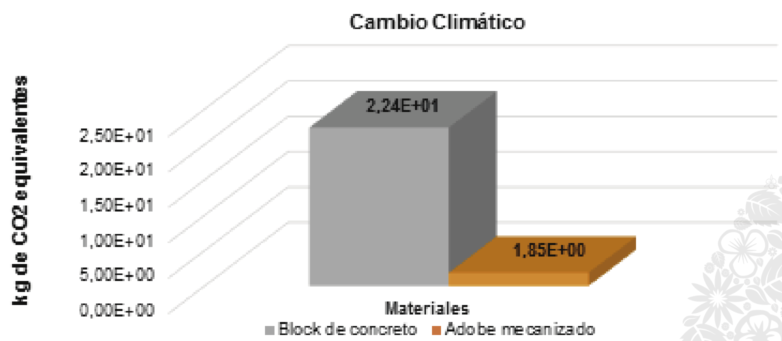


Figura 2. Comparación de CO2 eq/cm2 de muro

4| CONCLUSIONES

Estimando que el número de viviendas de tipo popular por construir en S.L.P. alcanzara para el año 2017 la cantidad de 11,000 unidades, y tomando como base una vivienda mínima con sup. const. de 45 m2 y 103.5 m2 de muros, por sustitución de block por BTC se alcanzan los siguientes beneficios:
De acuerdo a datos de emanaciones registradas, la cantidad de gases y partículas emitidas a partir de la fabricación de block y construcción con este material, se estima en (95.37 índice x 103.5 m2 x 11,000 viv.) 40,245,975 g., y si se sustituye por BTC, éstas se reducen hasta un 46.30%, disminuyendo así, la cantidad de gases y partículas tóxicas en (22.97 índice x 103.5 m2 x 11,000 viv.) 26,151,345 g., lo cual reduce el potencial de cambio climático, los efectos a la salud humana así como impactos como la acidificación. Adicionalmente, la cantidad de energía utilizada se reduce en un 87.13%, es decir, de 79.8 índice x 103.5 m2 x 1000 viv.) 90,852,300 MJ utilizando block de cemento y a (10.27 índice x 103.5 m2 x 11,000 viv.) 11,692,395 MJ empleando BTC's.

Bibliografia

- Algara, M., Cárdenas, Á., Arista, G., & Rodríguez, J. (2012). Diseño de bloques de suelo estabilizado para uso urbano en S.L.P., academiajournals, 14-16.
- Blanchard, S., & Reppe, P. (1998). Life Cycle Analysis of a Residential Home in Michigan. School of Natural Resources and Environmental-University of Michigan, 60.
- CADIS. (23 de 05 de 2015). Diplomado de Análisis de Ciclo de Vida para las Edificaciones. Mexico, D.F, Mexico.
- Chacón, J. R. (2008). Metodos de Apoyo para una Gestión Ambiental en las Organizaciones. Revista de la EScuela Colombiana de Ingeniería , 43-72.
- Fullana, P., & Puig, R. (1997). Análisis del Ciclo de Vida. Barcelona: Rubes editorial, 143.
- INECC, I. N. (2013). Inventario Nacional de Emisiones de Gases de Efecto Invernadero. México.
- ISO. (17/02/2015). ISO 14040 Environmental management-LCA. Principles and framework. Obtenido de iso.org: http://www.iso.org/iso/ catalogue_detail? csnumber=37456.
- ISO. (21 de 02 de 2015). ISO 14044 Environmental management -Life cycle assessment-Requirements and guidelines.
  Obtenido de iso.org: http:// www .iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=38498
- Lippiatt, B. (1998). Building for Environmental and Economic Sustainability. Construction and the Enviroment Proceedings, 8.
- Symonds, G. (1999). Construction and Demolition Waste Management Practices and their Economic Impacts. Report to DGXI-European Commission, 207.

ESTRATEGIA PARA LA ESTIMACIÓN DEL AGUA EVAPOTRANSPIRADA DE UNA CUENCA

MSc. Deborah Gaso*, Dr. Leonidas Carrasco-Letelier,A**

* Instituto Nacional de Investigación Agropecuaria (INIA), Programa de Cultivos,
INIA La Estanzuela, Ruta 50, km 11, Colonia, Uruguay. Tel.:+598-45748000.
Fax.:Tel.:+598-45748012. E-mail: dgaso@inia.org.uy
** Instituto Nacional de Investigación Agropecuaria (INIA), Programa de Producción
y Sustentabilidad Ambiental, INIA La Estanzuela, Colonia, Uruguay.
Tel.:+598-45748000. Fax.:Tel.:+598-45748012. E-mail: lcarrasco@inia.org.uy
A Red Uruguaya de Análisis de Ciclo de Vida, Uruguay.

RESUMEN:

La estimación de la huella hídrica, por el método de Water Footprint Network , o por la ISO 14046, será pronto una dimensión ambiental muy relevante de los productos agrícolas exportados de la región. En este marco, la cuantificación del agua de evapotranspiración es un componente importante tanto para el cálculo del volumen de agua verde como para el inventario del ciclo de vida de ISO14046. La evapotranspiración es a menudo estimada por el software CROPWAT, que requiere información que no siempre está disponible (por ejemplo, propiedades físicas del suelo) o difícil de calcular para unidades de paisaje (por ejemplo, cuencas). El presente trabajo presenta una estrategia para resolver el problema mencionado mediante la estimación de la evapotranspiración de la cuenca usando un modelo de balance energético de la superficie terrestre (METRIC), que trabaja con imágenes Landsat. Como ejemplo de la estrategia propuesta, se evaluó una cuenca de 193.357 hectáreas con un uso dominado por cultivos de soja en el período de enero a abril. Los resultados mostraron una pérdida de agua de la cuenca de 358 mm por evapotranspiración, cuando CROPWAT estima 232 mm. Por lo tanto, sería una herramienta de interés para los cultivos de América del Sur que requieren estimaciones de sus huellas de agua en condiciones de escasa información para usar CROPWAT.

Palabras clave:

Evapotranspiración, Sensoramiento Remoto, METRIC.

ABSTRACT:

The estimation of the water footprint, by Hoekstra's method, or by ISO 14046 will be soon a very relevant environmental dimension of agricultural products exported from the region. In this framework, the quantification of evapotranspiration water is an important component both for the calculation of green water volume and for the life cycle inventory of ISO14046. Evapotranspiration is often estimated by CROPWAT software, which requires information that is often unavailable (e.g. physical soil properties) or difficult to calculate for landscape units (e.g. watersheds). The current work show a strategy to solve the problem mentioned above by the estimation of watershed's evapotranspiration using a model of energy balance of the terrestrial surface (METRIC), that work with Landsat images. As an example of proposed strategy, we assessed a basin of 193,357 ha. with a land use dominated by soybeans crops in the period from January to April. The results showed a watershed's water lost of 358 mm by evapotranspiration, when the CROPWAT estimate 232 mm. Therefore, it would be a tool of interest for the crops of South America that require estimates of their water footprints.

1 Hoekstra, A. Y., Chapagain, A. K., Aldaya, M. M. & Mekonnen, M. M. 2011. The water footprint assessment manual: Setting the global standard. Routledge.

Keywords:

Evapotranspiration, remote sensing, METRIC.

1| NTRODUCCIÓN

La evaluación de la gestión del agua es muy relevante para la identificación de ecodiseños sostenibles en la producción agropecuaria regional. Tarea en la cual, la definición del consumo de agua por los cultivos es central tanto para la huella del agua (Aldaya et al., 2012) como la huella hídrica (ISO, 2014). Donde ambas metodologías recurren a la estimación de la evapotranspiración del cultivo utilizando las sugerencias de FAO (Allen et al., 2006) orientadas al cálculo del agua para el riego de los cultivos. Estimación que demanda tener estadísticas climáticas, propiedades de los suelo y características fenológicas de los cultivos. En forma alternativa, se han desarrollado algoritmos, basados en imágenes de satelite (e.g. LANDSAT), para cuantificar la evapotranspiración real del cultivo en las diferentes condiciones que se encuentra en una unidad de paisaje o cuenca (Irmak et al., 2011). Una de estas herramientas mencionadas es el modelo METRIC que emplea el balance energético de la superficie terrestre para estimar la evapotranspiración del cultivo (Allen et al., 2007a, 2007b). En este marco de trabajo, comparamos la estimación del agua evapotranspirada de una cuenca uruguaya empleando CROPWAT y METRIC, utilizando imágenes LANDSAT.

2| MATERIALES Y MÉTODOS

Estimando que el número de viviendas de tipo popular por construir en S.L.P. alcanzara para el año 2017 la cantidad de 11,000 unidades, y tomando como base una vivienda mínima con sup. const. de 45 m2 y 103.5 m2 de muros, por sustitución de block por BTC se alcanzan los siguientes beneficios:
De acuerdo a datos de emanaciones registradas, la cantidad de gases y partículas emitidas a partir de la fabricación de block y construcción con este material, se estima en (95.37 índice x 103.5 m2 x 11,000 viv.) 40,245,975 g., y si se sustituye por BTC, éstas se reducen hasta un 46.30%, disminuyendo así, la cantidad de gases y partículas tóxicas en (22.97 índice x 103.5 m2 x 11,000 viv.) 26,151,345 g., lo cual reduce el potencial de cambio climático, los efectos a la salud humana así como impactos como la acidificación. Adicionalmente, la cantidad de energía utilizada se reduce en un 87.13%, es decir, de 79.8 índice x 103.5 m2 x 1000 viv.) 90,852,300 MJ utilizando block de cemento y a (10.27 índice x 103.5 m2 x 11,000 viv.) 11,692,395 MJ empleando BTC's.

2.1. Área de estudio.

Se estudio la cuenca hidrográfica (193.357 ha.) del río San Salvador (33°28⊠13⊠S; 58°24⊠02⊠O) tributario del Río Uruguay. Una cuenca con un uso dominado por cultivos de soja.

2.2. CROPWAT.

Este es un software de FAO (Swennenhuis et al., 2006) que estima el consumo de agua de un cultivo según el método de FAO Penman-Monteith, usando como referencia un cultivo hipotético (superficie de pasto de altura uniforme, creciendo activamente y bien regado) para definir la evapotranspiración de referencia (ETo). Donde la evapotranspiración del cultivo (ETc) se estima multiplicado ET por el factor del cultivo (Kc) que cambia según el cultivo y su estado fenológico (Ec.1).

$$ET_c = ET_o \, x \, K_c \quad \text{Ecuación (1)}$$

Esta estimación requiere datos de posición del cultivo (latitud, longitud), estadísticas climáticas mensuales (temperatura mínima y máxima, humedad, velocidad el viento, horas de insolación, lluvia promedio) y propiedades del suelo (humedad, tasa de infiltración, reducción inicial de humedad). Información que en nuestro estudio fue obtenida de la estación meteorológica de INIA -La Estanzuela (Colonia, Uruguay), próxima a la zona de estudio y de la descripción de propiedades del suelo de Molfino (2012).

2.3. Estimación del agua evapotranspirada y algoritmos METRIC ™

El modelo METRIC (Allen et al., 2014) calculó el balance de energía de la superficie terrestre mediante el uso de la energía radiométrica estimada desde imágenes de satelitales. Donde la energía consumida por el proceso de evapotranspiración equivale a la diferencia o energía latente (LE) de la ecuación de energía de la superficie (Allen et al., 2007a, 2007b) (Ec. 2).

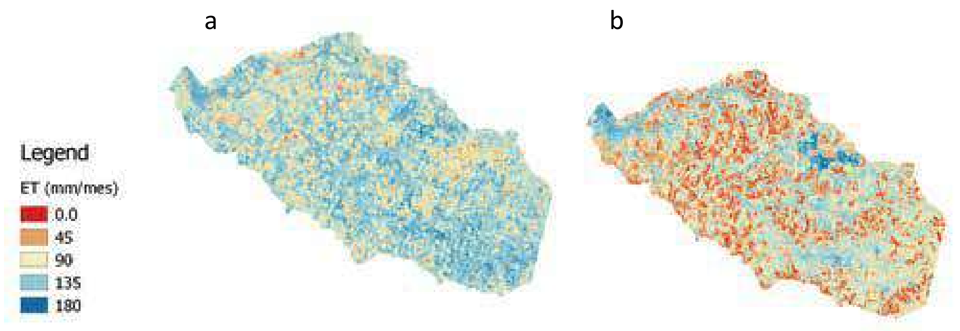
$$\lambda \, ET = LE = R_n - G - H \quad \text{Ecuación (2)}$$

donde λ es el calor latente de vaporización (J kg-1); Rn, el flujo de radiación neta real (W m-2), calculada de la banda de reflectancia medida por el satélite y la temperatura superficial; G es el flujo de calor dirigido hacia el suelo (W m-2), estimada desde Rn, la temperatura superficial e índices de vegetación; y H es el flujo de calor sensible (W m-2) estimado de los rangos de temperatura superficial, rugosidad y correcciones por viento. Rn y G se calcularon de acuerdo a Bastiaanssen et al. (1998) y el albedo según Tasumi et al. (2008). De esta manera, la estimación de la evapotranspiración mensual se realizó para cada pixel de la cuenca como una interpolación de la fracción de evapotranspiración de referencia diaria.
Esta estimación uso imágenes Landsat 7 Enhanced Thematic Mapper Plus (ETM +) y Landsat 8 Operational Land Imager (OLI) (path 225; row 83), libres de nubes para los meses de estudio (enero – abril, 2015). Las cuales fueron descargadas de la base de datos del USGS EROS (http://landsatlook.usgs.gov/viewer.html).

3| RESULTADOS Y DISCUSIÓN

La estimación de ETc con CROPWAT estimó un consumo de 232 mm sin riego. Esta estimación presentó como principal obstáculo la falta de disponibilidad de datos sobre las tasas de infiltración de los suelos. Una carencia de información frecuente para la mayor parte de los suelos. Además, este modelo asume una profundidad de suelos de por lo menos un metro, supuesto que no se ajusta a muchos suelos agrícolas o que presentan además un horizonte con baja conductividad hidráulica (Bt) (Altamirano et al., 1976). Por lo cual, el uso de esta metodología para estimar la ETc de cuencas sería de gran imprecisión dado que no es capaz de incorporar la heterogeneidad de situaciones, como la existencia de catenas de suelos.
Por otro lado, la estimación de la ETc por METRIC mostró una pérdida de agua de la cuenca equivalente a 358 mm debida a la evapotranspiración del cultivo de soja en el periodo de enero a abril. Es decir, estimó 126 mm adicionales que CROPWAT no consideró. Una diferencia que puede ser aún mayor si se hubiese incorporado una región inferior al 1% del área de la cuenca que está fuera de la cobertura de la imagen satelital utilizada.

Figura 1. Evapotranspiración acumulada mensual estimada para la cuenca del San Salvador en los meses de enero (a) y marzo (b).



Aunque ambos métodos estimaron una evapotranspiración en un orden de magnitud similar. Parece probable que CROPWAT esté subestimando la ETc de la cuenca al no poder incorporar adecuadamente la heterogeneidad de condiciones del suelo en la cuenca, así como la falta de disponibilidad de datos de conductividad hidráulica con mayor resolución espacial. De esta manera, el incremento en un 54% del valor de la ETc según METRIC, aunque debería refrendarse con datos experimentales de campo, es adecuado para el objetivo de la huella del agua y la huella hídrica: prevenir un agotamiento del recurso.
Finalmente, basado en las limitaciones encontradas en nuestro experimento sobre las propiedades físicas del suelo, queda la duda sobre cuánto puede ser el error en estimaciones que han usado CROPWAT a escala Planetaria como Mekonnen y Hoekstra (2011) donde la existencia de suelos someros o con un horizonte Bt no está considerado.

4| CONCLUSIONES

METRIC permite estimar la ETc del cultivo y capta la heterogeneidad de esta variable en la cuenca estudiada, sin las limitaciones de CROPWAT (e.g. variabilidad de suelos, especie de cultivo y fenología del mismo).

Referencias

Aldaya, M.M., Chapagain, A.K., Hoekstra, A.Y., Mekonnen, M.M., 2012. The water footprint assessment manual: Setting the global standard. Routledge.
Allen, R.G., Pereira, L.S., Raes, D., 2006. Crop evapotranspiration, FAO irrigation and drainage paper. FAO (Food and Agriculture Organization of the United Nations).
Allen, R.G., Pereira, L.S.,Raes, D., Smith, M. Crop evapotranspiration: Guidelines for computing crop requirements. Irrigation and Drainage Paper, vol. 56, p.300. 1998.
Allen, R.G., Tasumi, M. and Trezza, R. Satellite-Based Energy Balance for Mapping Evapotranspiration with Internalized Calibration. METRIC-Model. Journal of Irrigation and Drainage Engineering, 2007a, vol. 133, N° 4, p. 380–394.
Allen, R.G., Trezza, R., Tasumi, M. and Kjaersgaard, J. METRICTM Mapping Evapotraspiration at High Resolution using InternalizedCalibration Application Manual for Landsat Satellite Imagery. Version 3.0, University of Idaho, 2014.
Allen, R.G.,Tasumi, M., Morse, A., Trezza, R., Wright, J. L., Bastiaanssen, W., Kramber, W., Lorite, I., Robison, C. W. Satellite-Based Energy Balance for Mapping Evapotranspiration with Internalized Calibration. METRIC-Applications. Journal of Irrigation and Drainage Engineering, 2007b, vol. 133, N° 4, p. 380–395-406.
Altamirano, A., Da Silva, H., Durán, A., Echevarría, A., Panario, D., Puentes, R. Carta de Reconocimiento de Suelos del Uruguay. Tomo III: Descripción de las unidades de suelos. Dirección de Suelos y Fertilizantes, Ministerio de Agricultura y Pesca, Montevideo, Uruguay, 1976.
Bastiaanssen, W. G. M., Menenti, M., Feddes, R. A.., and Holtslag, A. A. M. A remote sensing surface energy balance algorithm for land (SEBAL): 1. Formulation. Journal of Hydrology, 1998, vol. 212-213, p. 198 – 212.
Irmak, A. Ratcliffe, I., Hubbard, K. G., Kamble, B., Kjaersgaard, J. Estimation of land surface evapotranspiration with a satellite remote sensing procedure. Great Plains Research, 2011, vol. 21, N° 1, p. 73–88.
ISO, 14046: Environmental Management Water Footprint – Principles, Requirements and Guidelines. International Organization for Standardization, Geneva, Switzerland, 2014.
Mekonnen, M.M., Hoekstra, A.Y. The green, blue and grey water footprint of crops and derived crop products. Hydrol. Earth Syst. Sci., 2011, vol. 15, 1577–1600.
Molfino, J. H., 2012. Características de Grupos CONEAT (MGAP). INIA – GRASS.
Swennenhuis, J., Smith, M., Van Halsema, G., Maraux, F., Gabriella, I., Wahaj, R., Munoz, G., 2006. CROPWAT. Water Resources Development and Management Service, Land and Water Development Division, Food and Agriculture Organization of the UN.
Tasumi, M., Allen, R. G., & Trezza, R. At-surface reflectance and albedo from satellite for operational calculation of land surface energy balance. Journal of hydrologic engineering, 2008, vol. 13, N° 2, 51-63.

Case studies in LCA

CILCA 2017

VII Conferencia Internacional de

Análisis de Ciclo de Vida en Latinoamérica

12 al 15 de junio de 2017

Medellín - Colombia

CARACTERIZAÇÃO DO CICLO DE VIDA DE UM SISTEMA INDUSTRIAL, INCORPORANDO AVALIAÇÃO DE RISCO: estudo de caso aplicado a uma biorrefinaria

CHARACTERIZATION OF THE LIFE CYCLE OF AN INDUSTRIAL SYSTEM, INCORPORATING RISK ASSESSMENT: study of case applied to a biorefinery

MSc. Leopoldo Deutsch*, PhD. Prof. Armando de Azevedo Caldeira-Pires**

* Universidade de Brasília, Faculdade de Tecnologia, Departamento de Engenharia Mecânica, Laboratório de Energia e Meio Ambiente. UNB - Campus Darcy Ribeiro – Asa Norte, Brasília, DF, Brasil. Telefone +55 61 3107-5003.
E-mail: leo@unb.br
** Universidade de Brasília, Faculdade de Tecnologia, Departamento de Engenharia Mecânica, Laboratório de Energia e Meio Ambiente. UNB - Campus Darcy Ribeiro – Asa Norte, Brasília, DF, Brasil. Telefone +55 61 3107-5003.
E-mail: armando@unb.br

RESUMO:

Para atender as crescentes demandas dos mercados, as indústrias manipulam volumes cada vez maiores de massa e energia em condições extremas de temperatura, pressão e toxicidade, causando impactos crônicos que somados aos riscos de eventos transientes inerentes aos processos críticos, introduzem perigos que ameaçam a vida, o meio ambiente e a economia, em cenários de incertezas epistêmicas e estocásticas. O processo decisório neste contexto complexo exige o uso de ferramentas que orientem soluções de menor impacto e risco. Metodologias como Avaliação do Ciclo de Vida (ACV) e Avaliação de Risco (AR), apesar de utilizarem insumos muitas vezes semelhantes, são aplicadas isoladamente. Propomos introduzir em ACV abordagens que permitam avaliar também impactos produzidos por eventos transientes. O método proposto é aplicado a processo específico de uma biorrefinaria, e produz resultados que podem contribuir para melhor tomada de decisão quanto aos impactos, riscos e medidas de mitigação.

Palavras chave:

Processo de tomada de decisão; Incertezas Epistêmicas e Estocásticas; Probabilidade e Risco; Operação em regime permanente e eventos transientes; Avaliação do Ciclo de Vida (ACV); Avaliação de Risco (AR).

ABSTRACT:

In order to meet growing market demands, industries handle increasing amounts of mass and energy under extreme conditions of temperature, pressure and toxicity, causing chronic impacts that added to the risks of transient events inherent in critical processes, introduce hazards that threatens life, environment and economy, in scenarios of epistemic and stochastic uncertainties. The decision making process in this complex context requires the use of tools that guide solutions of less impact and risk. Methodologies such as Life Cycle Assessment (LCA) and Risk Assessment (AR), although using often similar inputs, are applied in isolation. We propose to introduce in LCA approaches that allow evaluating also impacts produced by transient events. The proposed method is applied to a specific biorefinery process, and produces results that may contribute to better decision making regarding impacts, risks and mitigation measures.

Keywords:

Decision making process; Epistemic and stochastic uncertainties; Probability and Risk; Operation in permanent regime and transient events; Life Cycle Assessment (LCA); Risk Assessment (AR)

1| INTRODUÇÃO

Cluzel et al (2014) e Burgherr et al (2012) destacam que ao longo da evolução tecnológica que deu origem aos atuais sistemas industriais, pouca preocupação foi dedicada aos impactos sobre a vida e o meio ambiente causados por sua operação em regime permanente e pelos prejuízos de imprevisíveis eventos transientes , o que permitiu, por exemplo, a emissão descontrolada de gases de efeito estufa e outros poluentes, e a ocorrência de eventos transientes como o de Chernobyl. Reagindo a isso, sociedade e governos passaram a exigir controles cada vez mais rígidos para as emissões (AICHE,1992) e para a prevenção de eventos transientes, levando ao desenvolvimento de metodologias de apoio à decisão como ACV, que aborda impactos ambientais produzidos pela operação em regime permanente, e AR, coleção de métodos que auxiliam na identificação de perigos, riscos, probabilidades e impactos de eventos transientes (Sovacool et al, 2016). Incertezas epistêmicas e estocásticas (Li et al, 2014) presentes nos dados de inventário e em outras variáveis de ACV e AR se propagam pelos modelos e contaminam seus resultados, a identificação de perigos e riscos e a estimação de probabilidades. Diversas técnicas são utilizadas, sendo que destacamos:

Método	Descrição
Estimação de impactos ambientais	Utilização do método da matriz inversa, com a construção da Matriz Tecnológica (G) e de Intervenção Ambiental (H).
Estimação de incertezas em dados de entrada	Avaliação da incerteza em componentes de entrada dos inventários pode ser feita por meio de distribuição de probabilidades e sua quantificação pelo cálculo da variância ou do desvio padrão
Análise de Cenários	Descreve uma situação vigente e que permite prever sua evolução no tempo a partir dos parâmetros atuais mais relevantes
Análise de Sensibilidade	Identifica os parâmetros que mais contribuem para a incerteza dos modelos
Simulação de Monte Carlo	Qualquer método que resolva um problema por meio da geração de números aleatórios adequados e uma abordagem estatística baseada em algoritmos computacionais
Análise Preliminar de Perigos (APP)	Planilha construída a partir da identificação de perigos (eventos iniciadores de acidentes, como a liberação descontrolada de substância perigosa ou energia), do sistema em análise.
Árvore de Eventos (ETA)	Técnica gráfica para representação de seqüências mutuamente excludentes de eventos após um evento iniciador.

Quadro 1 - Métodos utilizados em ACV e AR para mensuração de incertezas, perigos e probabilidades
Fonte: Jarke et al, 1998; Pesonen et al, 2000; ISO 14040, 2009; GUM, 2012; ISO 31000, 2012; Cluzel et al, 2014; Cairns et al, 2015; Groen et al, 2016.

Mesmo que ACV e AR produzam resultados consistentes e adequados aos seus propósitos, suas recomendações isoladamente não abrangem todo o espectro de eventos de um sistema industrial. Propomos uma metodologia que incorpore em ACV técnicas de AR, expandindo o potencial do método para avaliar, em um mesmo procedimento, impactos crônicos e derivados de eventos transientes.

A operação em regime permanente produz efeitos cumulativos no tempo que podem passar despercebidos ou são ignorados até o momento em que os prejuízos se tornam evidentes.
Eventos transientes, ou acidentes, relacionam-se à manifestação de perigos e riscos, conhecidos ou não, ao longo do ciclo de vida de um sistema industrial.

2| METODOLOGIA

Tendo por base a estrutura de ACV, propomos incorporar em suas etapas atividades hoje de AR, resultando em novo framework de processos, do qual mostramos visão simplificada, evidenciando as principais modificações:

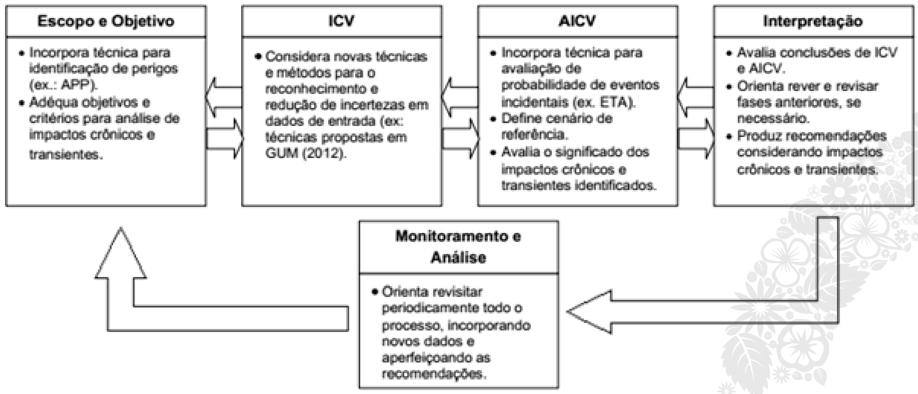


Figura 1 - Framework proposto para incorporação de técnicas de AR em ACV
Fonte: do autor

As principais equações utilizadas são destacadas:

Equações de interesse		
Equação 01	**Equação 02**	**Equação 03**
Ajuste de dados Tipo A (medição)	**Matriz Inversa**	**Correlação de Spearman**
$s^2_{(x_k)} = \frac{1}{n-1}\sum_{j=1}^{n}(x_j - \bar{x})^2$	$\vec{y} = H.G^{-1}.\vec{u}(1)$	$r_j = \frac{\sum_i (p_{(i)j} - \bar{p}_j)(g_i - \bar{g})}{\sqrt{\sum_i (p_{(i)j} - \bar{p}_j)^2 \sum_i (g_i - \bar{g})^2}}$

Quadro 2 - Equações de interesse

Fonte: eq. 01-extraído de GUM, 2012; eq. 02-extraído de Heijungs e Suh, 2002; eq. 03-extraído de Groen et al, 2016.

Onde necessário, foi utilizada aproximações pela Simulação de Monte Carlo (Yoriyaz, 2009), com o uso da distribuição normal, empregando-se testes de normalidade e homocedasticidade para comprovar a adequação da escolha. Três processos de uma biorrefinaria foram selecionados para análise. APP foi empregada para a identificação de perigos e eventos iniciadores, que foram utilizados em ETA para a determinação das probabilidades envolvidas (ISO 31010, 2012). A construção do ICV se deu por meio de valores de medição, ajustado de acordo com a equação 01, e dados de literatura (assumidos como isentos de incerteza) dando origem à Matriz de Processos, abaixo. Para o cálculo do AICV foi utilizada a equação 02, e para o cálculo das incertezas nas amostras avaliadas, a equação 03.

		Processos		
	Commodity	Preparação da *cana in-natura*	Geração de energia elétrica	Destilação, Fermentação e Tancagem
Matriz Tecnológica (*G*)	Cana de açúcar (kg)	(-) 11760	(-) 2940	0
	Energia elétrica (kWh)	(-) 23,52	(+) 152,88	(-) 10
	Álcool (m^3)	0	0	(+) 1
Matriz Intervenção (*H*)	Água residual (m^3)	65,62	0	2,15
	CO^2 (kg)	0	2290	760
	Cinza (kg)	0	220	0

Tabela 1 – Matriz de Processos
Fonte: do autor

APP permite construir a lista de perigos dos processos de interesse, e selecionar sub-processo para identificação de eventos iniciadores e aplicação de ETA.

Lista de Perigos			
Processo	**Preparação de cana in-natura**	**Geração de energia elétrica**	**Destilação, Fermentação e Tancagem**
Tipo de Perigo	Danos físicos	Explosão de caldeira, vazamento de vapor, espalhamento de material em combustão.	Vazamento de material em alta temperatura, incêndio, explosão dos tanques, vazamento de vinhoto.

Quadro 3 - APP - Lista de perigos mais relevantes

Processo: Geração de energia elétrica, sub-processo: explosão em caldeira	
Eventos iniciadores	Falha de monitoramento, falha em válvula de alívio, falha em procedimento de emergência
Elementos indutores	Obsolescência, manutenção inapropriada ou inexistente, falha de treinamento, procedimento operacional inadequado.

Quadro 4 - APP - Análise parcial de processo, para aplicação de ETA
Fonte: do autor

A análise dos impactos de um sistema industrial deve levar em consideração aspectos sociais, econômicos e ambientais, sendo que para estes utilizamos a Matriz Inversa (eq. 02), refinando-se os valores de entrada por meio de Análise de Sensibilidade com o uso do coeficiente de correlação de Spearman (eq. 03).

3| RESULTADOS E DISCUSSÃO

AICV mostra que para cada 100 litros de álcool produzidos são lançados na natureza aproximadamente 90 kg de CO2, 138 litros de água residual e 1 kg de cinzas. A avaliação da incerteza nos dados por processo mostrou que:

Processos		Preparação de cana in-natura	Geração de energia elétrica	Destilação, Fermentação e Tancagem
Incerteza nos dados de entrada	Percentual explicado pelos dados:	97%	96%	95%
	Percentual explicado por outros fatores:	3%	4%	5%
	Principal contribuinte da incerteza:	CO^2, com variação entre 77% e 92%.		

Tabela 2 - Avaliação de incertezas em dados
Fonte: do autor

Para o sub-processo “Explosão em caldeira” a ETA estimou a probabilidade de falha em 0,00005% ao ano, a partir das condições colocadas. O risco desse segmento da biorrefinaria pode ser estimado pela ponderação a probabilidade de ocorrência do evento e o impacto provocado, cuja dimensão ambiental pode considerar resultado de AICV, alem de aspectos de dimensões econômicas e sociais. Para o caso apresentado, apesar da baixa probabilidade, o potencial de dano físico e econômico é elevado, o que nos leva a considerar o risco como “médio”. É recomendável reforço na manutenção/inspeção dos equipamentos para a redução do risco para “baixo”. O impacto crônico é produzido principalmente pelo lançamento de águas residuais e CO2, recomendando ações no sentido do reaproveitamento da água e estudos para redução na emissão de gases de efeito estufa.

4| CONCLUSÕES

É apresentado método genérico para avaliação de impactos crônicos e transientes, por meio de integração das metodologias de ACV e AR. Os resultados obtidos permitiram aos gestores melhores informações para a tomada de decisão quanto à melhor opção de solução em termos de riscos e impactos ambientais, considerando aspectos sociais, ambientais e econômicos, além de observar exigências legais de controle de emissões e segurança das instalações. Maior aprofundamento e estudos ainda são exigidos para o aperfeiçoamento da solução, notadamente com a introdução de soluções automatizadas que permitam estender as análises para ambientes de maior complexidade.

Referências

ABNT 14040. ABNT NBR ISO 14040 - Gestão ambiental - Avaliação do ciclo de vida - Princípios e estrutura, 2009, p.21.
ABNT 31000. ABNT NBR ISO 31000 - Gestão de riscos - Princípios e diretrizes. 2009, p.30.
ABNT 31010. ABNT NBR ISO 31010 - Gestão de riscos - Técnicas para o processo de avaliação de riscos. 2012, p.96.
AICHE. Guidelines for Hazard Evaluation Procedures: with worked examples, 3ª ed. American Institute of Chemical Engeeniers, New York, 1992. ISBN 0-8169-0491-X
Burgherr, P.; Eckle, P.; Hirschberg, S. Comparative assessment of severe accident risks in the coal , oil and natural gas chains. Reliability Engineering and System Safety, 2012, nº 105, p.97–103.
Cairns, G., Goodwin, P. & Wright, G. A decision-analysis-based framework for analyzing stakeholder behaviour in scenario planning. European Journal of Operational Research, 249(3), 2015, pp.1050–1062.
Cluzel, F.; Yannou, B.; Millet, D.; Leroy, Y. Exploitation scenarios in industrial system LCA. International Journal of Life Cycle Assessment, 2014, nº 19(1), p.231–245.
Curran, M.A., Mann, M. & Norris, G.The international workshop on electricity data for life cycle inventories, 2005. Journal of Cleaner Production. p. 853–862.
Groen, E.A. et al. Methods for global sensitivity analysis in life cycle assessment. The International Journal of Life Cycle Assessment, 2016.
GUM. Avaliação de dados de medição. Guia para a expressão de incerteza de medição. Duque de Caxias, RJ. INMETRO/CICMA/SEPIN, 2012
Heijungs, R. & Suh, S. The Computacional Structure of Life Cycle Assessment. 2002, Dordrecht, The Netherlands: Kluwer Academic Publishers.
Heijungs, R.Sensitivity coefficients for matrix-based LCA. International Journal of Life Cycle Assessment, 2010, nº 15, p.511-520.
Jarke, M., Bui, X.T. & Carroll, J.M. Scenario Management: An Interdisciplinary Approach. Requirements Engineering, 3(3–4), 1998, pp.155–173.
Li, Yiping; Chen, Jianwen; Feng, L., 2014. Dealing with uncertainty: a survey of theories and practices. IEEE Transactions on Knowledge and Data Engineering, 2015, nº 25(11), p.1–25.
Pesonen, H. et al. Framework for scenario development in LCA. The International Journal of Life Cycle Assessment, 5(1), 2000. pp.21–30.
Sovacool, B.K.; Kryman, M.; Laine, E.Profiling technological failure and disaster in the energy sector : A comparative analysis of historical energy accidents. Energy, 2016, nº 90(2015), p.2016–2027.
Yoriyaz, H. Monte Carlo Method : principles and applications in Medical Physics. Revista Brasileira de Física Médica, 2009, nº 3(1), p.141–149.

LIFE CYCLE ASSESSMENT OF BUS RAPID TRANSIT (BRT): A CASE STUDY OF TRANSCARIOCA

Isabelle Duran Martins*, M.Sc. Ana Carolina Maia Angelo*, M.Sc. Dejair de Pontes Souza*, Ph.D. Rogerio de Aragão Bastos Valle*

* Production Management Advanced Systems Laboratory, Federal University of Rio de Janeiro, Production Engineering Program. Cidade Universitária, Ilha do Fundão, Rio de Janeiro, RJ, Brazil. +5521 3622-3545.
E-mail: belle_duran@poli.ufrj.br

ABSTRACT:
Seen as sustainable transport option, the Bus Rapid Transit (BRT) system has been largely adopted as public transport alternative with low cost, quick implementation and lower negative environmental impact when compared to other transit modes. In most cases, the environmental impact assessments of a transport mode are based exclusively on emissions caused by fuel consumption. However, passenger vehicles also need a large and complex system for operation. This paper focuses on assessing the environmental performance of BRT Transcarioca, in the city of Rio de Janeiro, based on a life cycle perspective in order to identify the most significant environmental impacts associated to each life cycle phase and its relative contribution to the overall environmental impact. The Life Cycle Assessment (LCA) methodology was applied according to ISO 14040 standards and it was carried out using Umberto® software for modeling processes and mass flows. The system boundary of this study is from raw material extraction to BRT system operation, including the infrastructure and vehicle material production, infrastructure (road and stations) and vehicle manufacture, BRT operation and maintenance for over 20-years lifetime. The ReCiPe method was used for Life Cycle Impact Assessment (LCIA) and results show that the life cycle phases with greater contribution to environmental impacts are infrastructure construction and BRT operation.

Keywords:
Life Cycle Assessment; Transport Systems; Bus Rapid Transit; Environmental Impacts; Rio de Janeiro.

1 | INTRODUCTION

In order to host 2016 Olympic and Paralympic Games, Rio de Janeiro city investments in public transport included the construction of 4 new Bus Rapid Transit (BRT) lines. One is BRT Transcarioca that connects Rio's international airport until the western part of the city, where most of Olympic Games took place. It has 39 km extension and 47 stations (ITDP, 2015). A poorly planned urban transportation influences public transport users to move to private vehicles. Therefore, it causes an increase in pollutants emission, decrease of energy efficiency and a higher demand for infrastructure area (Herdy et al., 2012). This article aims to evaluate the environmental performance of BRT Transcarioca, from the perspective of Life Cycle (LC), in order to quantify the potential environmental impacts related, ranging from natural resources extraction for construction until BRT operation.

2 | METHODOLOGY

The BRT Transcarioca environmental performance assessment followed the Life Cycle Assessment (LCA) methodology according to ISO 14.040 and ISO 14.044 (ISO, 2006), and it was carried out using Umberto® software. The Life Cycle Impact Assessment (LCIA) was carried out through ReCiPe Midpoint (H) w/o LT (GOEDKOOP et al., 2013), considering all its 18 impact categories: Agricultural Land Occupation (ALO), Climate Change (CC), Fossil Resource Depletion (FD), Freshwater Ecotoxicity (FET), Freshwater Eutrophication (FE), Human Toxicity (HT), Ionizing Radiation (IR), Marine Ecotoxicity (MET), Marine Eutrophication (ME), Mineral Resource Depletion (MRD), Natural Land Transformation (NLT), Ozone Depletion (OD), Particulate Matter Formation (PMF), Photochemical Oxidant Formation (POF), Terrestrial Acidification (TA), Terrestrial Ecotoxicity (TET), Urban Land Occupation (ULO) and Water Depletion (WD).
Most of transportation LCA studies focus on one or a few impact categories as seen on Cui et al. (2010) and Andrade and D'Agosto (2016). While this may facilitate the interpretation of results, it also creates a risk of excluding relevant aspects from the analysis. In addition, according to JCR-IRS (2010), the choice of impact categories should be extensive in a way that makes possible to consider all environmental questions relevant related to the system in analyzes, except when a limitation is defined on the scope, as in a carbon footprint.
As the main function of a BRT system is to carry passengers, the functional unit chosen for BRT Transcarioca is 1 passenger kilometer travelled (pkt). Data used for pkt calculation is 1 year passenger history, average distance travelled by passenger (11km) and 20 years road lifetime (Infraestrutura Urbana, 2011; ITDP, 2015). Articulated buses has a service life of 10 years and, for 20 years LC, it was considered one full bus replacement (Hidalgo et al., 2013).
BRT Transcarioca LCA covers raw material extraction and transportation; infrastructure construction, that includes the construction of road, stations and engineering structures such as viaducts; infrastructure maintenance; fuel production; vehicle manufacture; vehicle maintenance and BRT system operation, including electricity

consumed by stations. The end of life phase was not included due to the high complexity for evaluating final disposal and materials reuse options (Chester and Horvarth, 2009). Chester (2008) justified it by highlighting that the study is still considering the phases with higher contribution for emissions inventory, and thus results are more conservative as it is consistent to assume that end of life phase's contributions are positive for the emissions inventory.

For Life Cycle Inventory Analysis, information related to infrastructure construction, fuel production and BRT operation were retrieved from BRT system and literature review. Vehicle manufacture inventory was estimated through a comparison by mass between a common bus production given by Ecoinvent database and an articulated bus chassis. The data for maintenance and raw material production were filled using Ecoinvent v. 3.1 database, adapted to local context when possible. It should be recognized that the gap of inventory data is a limiting factor for LCA development in Brazil, especially for civil construction due to enterprises concern about providing information of their productive processes and the risk of plagiarism or to convey a negative image (Filho et al., 2016). In order to obtain more reliable results and to make LCA study case doable, it was necessary to limit system boundary, same as seen in Teri (2012) and Andrade and D'Agosto (2016).

3 | RESULTS AND DISCUSSION

Figure 1 shows that infrastructure construction and BRT operation were the phases with highest level of emissions for the majority of impacts categories analyzed, i.e. both are the main contributors to environmental performance of BRT Transcarioca.

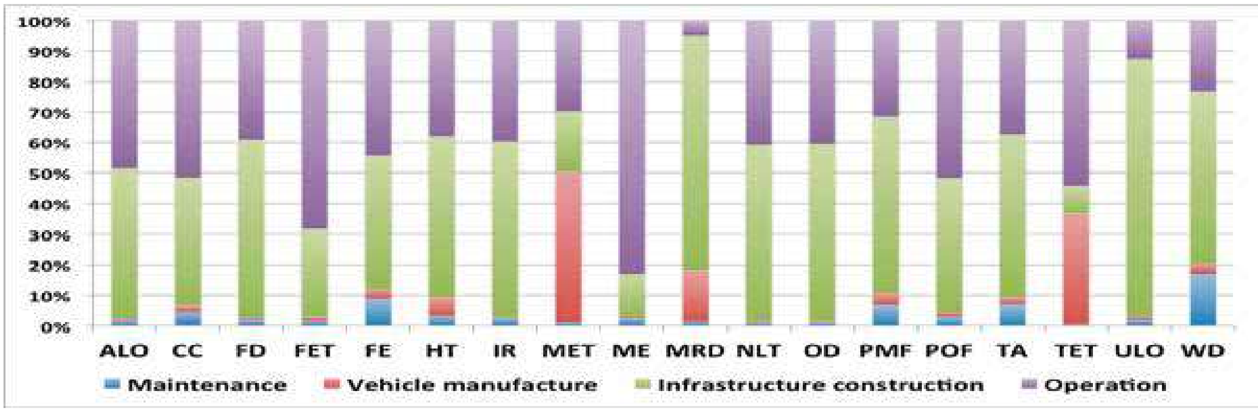


Figure 1: Contribution of BRT Transcarioca life cycle phases for each impact category

For infrastructure construction phase, bitumen production is the main process responsible for the majority of negative environmental impacts. In the vehicle manufacture phase, steel production has higher contribution for impact categories. Regarding operation phase, the most significant process is diesel production. Although oil diesel in Brazil is made of a blend between diesel and 7% biodiesel, which helps to reduce related emissions, it additionally causes higher eutrophication impacts due to agriculture fertilizers.

Some impact categories are more relevant for Rio de Janeiro city, such as CC, PMF and POF. Transport sector is responsible for 34.5% of total GHG emissions, being the largest contributor (SMAC, 2013). Also, law 5.248/2011 – Municipal Law on Climate Change and Sustainable Development establishes reduction goals for anthropic GHG emissions (RIO DE JANEIRO, 2011). Regarding to PMF and POF categories, its importance is highlighted by the fact that the Rio de Janeiro city air quality is constantly monitored for CO, SO2, O3, NOx and PM10 (SMAC, 2012). This monitoring also reveals that O3 is the pollutant with higher concentration in the city, sometimes being above limits nationally established for air quality standards. Operation and infrastructure construction are the phases that mostly contribute for these three impact categories. Of course for CC, operation has higher impact (51,63%) due to diesel consumption. Infrastructure construction has large contribution to PMF due to bitumen production since it emits volatile organic compounds (VOCs). Finally, these phases are the most significant ones for POF as photochemical oxidants are products of reactions between NOx and VOCs.

Sensitivity analysis was performed by running the model for an increased road lifetime (30 years). It revealed that, for a longer lifetime, impacts related to infrastructure construction tend to decrease. It happens because operation phase has increasing emissions contributions during lifetime while the other has only one contribution during LC. In that case, BRT operation phase has higher impact than infrastructure construction, except for MRD, PMF, ULO and WD impact categories.

4| CONCLUSIONS

This paper has applied LCA methodology to BRT Transcarioca from natural resources extraction until BRT operation, aiming to evaluate its environmental performance and to identify which are the LC phases and processes with higher potential environmental impacts. Results showed that, for a 20 years LC, infrastructure and BRT operation phases have higher impacts for the majority of impact categories. Besides, relative contribution of operation environmental impacts increases with a longer time horizon. Brazil has an advantage of using biodiesel as mixture to fossil diesel, and having a mainly renewable energy matrix. This study also contributes for identifying possible measures to be applied in order to reduce potential environmental impacts in future BRT systems. Regarding infrastructure construction impacts, it is recommended to improve cement production for reducing impacts related to concrete and also improve steel industry through increasing its energy efficiency.

The gap of inventory data is a limiting factor for LCA development in Brazil. Because of that, one of the main challenges for this paper was data collection, since the use of foreign databases can increase related uncertainty. It is recommended LCI studies in order to enrich national database and minimize future researches uncertainties. Lastly, a desirable continuation would be a comparative study with regular bus lanes that had their itineraries changed or were extinct due to the insertion of BRT Transcarioca into Rio de Janeiro transport system.

References

ANDRADE, C. E. S., D'AGOSTO, M. A., 2016, "Energy Use And Carbon Dioxide Emissions Assessment In The Lifecycle Of Passenger Rail Systems: The Case Of The Rio De Janeiro Metro". Journal of Cleaner Production, n.126 (Abr), pp. 526- 536.

CHESTER, M., 2008, Life-cycle Environmental Inventory of Passenger Transportation in the United States. Ph.D. thesis. Institute of Transportation Studies, University of California-Berkeley, Estados Unidos.

CHESTER, M., HORVATH, A., 2009, Environmental assessment of passenger transportation should include infrastructure and supply chains. Environmental Research Letters, v. 4, n. 2 (Jun), 8 pages.

CUI, S., NIU, H., WANG, W. et al., 2010, Carbon footprint analysis of the Bus Rapid Transit (BRT) system: a case study of Xiamen City. International Journal of Sustainable Development & World Ecology. V.17, n.4 (Jul), 8 pages.

European Commission - Joint Research Centre - Institute For Environment And Sustainability (JCR-IES), 2010, International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010. Translated by Luiz Marcos Vasconcelos. EUR 24708EN. Luxembourg. Publications Office of the European Union.

FILHO, O. C., JUNIOR, N.L.S., LUEDEMANN, G., 2016, A Avaliação de Ciclo de Vida como Ferramenta para Formulação de Políticas Públicas no Brasil, Texto para Discussão do IPEA, No 2205.

GOEDKOOP M.J., HEIJUNGS R, HUIJBREGTS M. et al., 2013, ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; First edition Report I: Characterisation; May, 2013.

HERDY, R. R., MALBURG, C. H. R.; SANTOS, R. T, 2012, Transporte urbano: O papel do BNDES no apoio à solução dos principais gargalos de mobilidade. BNDES 60 anos: perspectivas setoriais. Rio de Janeiro: Banco Nacional de Desenvolvimento Econômico e Social, 310-346.

HIDALGO, D., PEREIRA, L., ESTUPIÑÁN, N. et al., 2013, "Transmilenio BRT System In Bogota, High Performance And Positive Impact – Main Results Of An Ex-Post Evaluation". Research in Transportation Economics, v.39, n.1 (Mar),133-138.

INFRAESTRUTURA URBANA, 2011, BRT Transcarioca. Available at: http://infraestruturaurbana.pini.com.br/solucoes-tecnicas/13/artigo254421-1.aspx. [Accessed September 29, 2016].

Instituto de Políticas de Transporte e Desenvolvimento (ITDP), 2015, Análise de Impacto do BRT Transcarioca na Mobilidade Urbana do Rio de Janeiro, 64 p.

ISO, 2006, ISO 14040: Environmental management – life cycle assessment – principles and frameworks. International Standard 14040. International Organisation for Standarsisation. Geneva.

RIO DE JANEIRO, 2011, Law No 5.248 – Municipal Law on Climate Change and Sustainable Development.

SMAC, 2012, Qualidade do ar na cidade do Rio de Janeiro – Relatório da rede MonitorAr-Rio 2011-2012. Available at: http://www.rio.rj.gov.br/dlstatic/10112/3252594/4114836/RelatorioMonitorar20112012.pdf. [Accessed April 6, 2017].

SMAC, 2013, Greenhouse gas emissions inventory of the city of Rio de Janeiro in 2012 and updating of the municipal plan of action for emissions reduction.
Available at: http://www.rio.rj.gov.br/dlstatic/10112/1712030/4114527/CRJ_InventarioGEE2012_resumo_tecnicoINGLESFINAL1.pdf. [Accessed April 4, 2017].

TERI, 2012, Life cycle analysis of transport modes New Delhi (Volume 1). The Energy and Resources Institute, New Delhi.

ANALYSIS OF ALUMINUM PRIMARY PRODUCTION FROM EXERGY AND THERMOECONOMIC APPROACHES

Eduardo Carrera*, Freddy Malpica, Zoe Castillo***, Oscar González****
Professor, Universidad Simón Bolívar,

Department of Mechanics,
Sartenejas, Caracas, Edo. Miranda, Venezuela.
+58-212-906-4060
E-mail: {ecarrera, ogonza}@usb.ve
** Professor, Universidad Simón Bolívar, Department of Thermodynamics and Transfer Phenomena,
Sartenejas, Caracas, Edo. Miranda, Venezuela.
+58-0212-906-3740
E-mail: fmalpica2003@yahoo.com
*** Universidad Simón Bolívar, Degree Program in Chemical Engineering,
Sartenejas, Caracas, Edo. Miranda, Venezuela.
+58-0412-604-2493
E-mail: {09-11270}@usb.ve

ABSTRACT:
Aluminum is currently the most important non-ferrous mineral in industry, which is mainly obtained from bauxite mines through two successive processes: Bayer Process and Hall-Héroult Process. Both involve high energy consumption and produce a set of wastes, causing economic disadvantages and environmental impacts that compromise their sustainability. Although both processes have been continuously improved over the last hundred years, their efficiency continues to be quite low. Being essential the study of energy degradation and associated costs in this process, this research analyzes the primary production of aluminum from an exergetic and thermoeconomic approach. The results suggest that the greatest degradation of exergy occurs in the Bayer process, implying also a higher relative cost increase than in the case of Hall-Héroult process. The exergoeconomic factor indicates that technological improvements are economically viable, which would result in a better use of exergy throughout the processes. However, the approach used should be complemented by a Life Cycle Assessment (LCA), since it does not directly quantify the environmental impact of this degradation.

Keywords:
Exergy, Thermoeconomic Analysis, Exergoeconomic Analysis, Aluminum, LCA

1 | INTRODUCTION

Nowadays, aluminum is the most important non-ferrous metal used in industry (Balomenos et al. 2011). In the last 100 years it has been obtained mainly from bauxite and two successive processes are usually employed for this purpose: Bayer process, through which alumina (aluminum oxide contained in the bauxite), is extracted; and Hall-Héroult process, from which aluminum is obtained by subjecting the alumina to an electrolytic reduction. Although these processes have been improved constantly, its low yields and its environmental impacts persist (Balomenos et al. 2011). As a result, aluminum industry is the highest energy consumer over the world, it is also among the major CO2 producers and generates a vast amount of solid wastes (Balomenos et al. 2011; Gomes et al. 2016).
Due to the high energy consumption in aluminum industry, the purpose of this study is to model the primary aluminum production from an exergetic and thermoeconomic approach. The model includes the exergertic and thermoeconomic analyses of the Bayer and Hall-Héroult processes. The costs of the resources and products are allocated proportionally to their respective exergies, which adequately reflects their respective useful effects. Besides, the model evaluate the costs of exergy destruction and losses, and their influences in the costs formation of the processes' products: alumina and aluminum. The results and analyses show the advantages and limitations of this approach.

2| METHODOLOGY

The method used in this study was based on the methodology described by Querol et al. (2012). The fundamental stages for primary aluminum production were studied. In Figure 1, a schematic image of both processes (Bayer process and Hall-Héroult process) are shown. The system's inputs and outputs flows were obtained by employing properties from the results achieved in Balomenos et al. 2011, and the data shown in Dean (1998).The mass balance closure was verified and then the exergy destruction was calculated using fundamentals definitions indicated by Dean (1998).

Each current was identified as a resource, product or waste. Themoeconomic cost flows were defined for each resource and product, and expressed in monetary units per unit of time (dollar.s-1), their values were computed from Husband et al. 2009, Rusal (2017) and ter Weer (2007). A thermooeconomic balance was carried out for each process by considering that the thermoeconomic cost flow of outputs should be equal to thermoeconomic cost flow of inputs plus the fixed cost flows of investment, operation and maintenance. Besides, a unit exergoeconomic cost was defined for each input or output as the rate of thermoeconomic cost flow per unit of exergy flow (dollar.kJ-1).

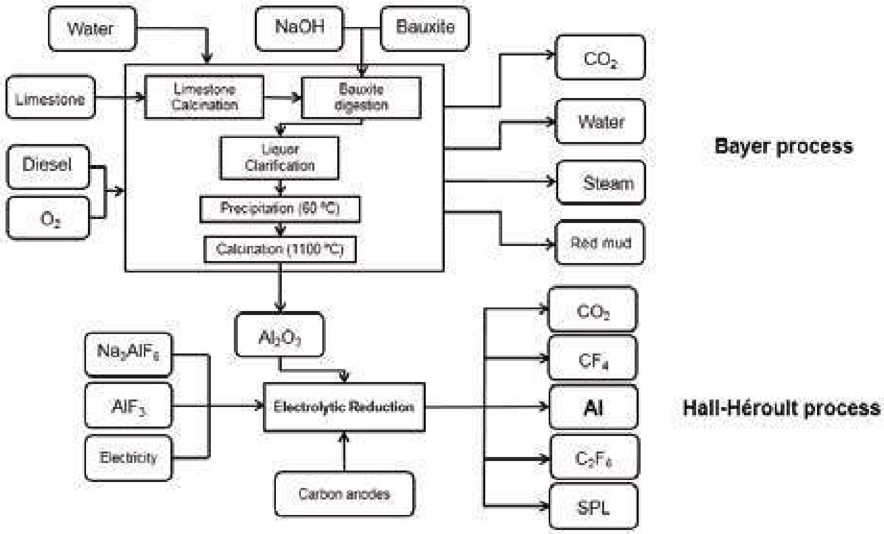


Figure 1. General scheme of aluminum production

For both processes, three indicators defined by Querol et al. (2012) were calculated: exergetic efficiency (ψ), relative cost increase (r_i) and exergoeconomic factor (f_i), whose expressions are shown in (1), (2) y (3), respectively.

$$\psi \equiv \frac{\dot{B}_{P,i}}{\dot{B}_{r,i}} \qquad (1)$$

$$r_i \equiv \frac{c_{P,i} - c_{R,i}}{c_{R,i}} \qquad (2)$$

$$f_i \equiv \frac{\dot{Z}_i}{\dot{\Pi}_{l,i} + \dot{\Pi}_{d,i} + \dot{Z}_i} \qquad (3)$$

Where $\dot{B}_{P,i}, \dot{B}_{r,i}$ are exergy flows of products and resources; $c_{r,i}, c_{P,i}$, ,are unit exergoeconomic cost of resources and products; $\dot{Z}_i, \dot{\Pi}_{l,i}, \dot{\Pi}_{d,i}$ are fixed cost flow, and thermoeconomic cost flow related to exergy losses and exergy destruction.

3| RESULTS AND DISCUSSION

By applying the methodology above, the three indicators shown in equations (1), (2) y (3) were calculated.

Table 1. Exergetic efficiency, relative cost increase and exergoeconomic factor related to the processes studied.

Process	ψ	r	f
Bayer	0.02	80.86	0.33
Hall-Héroult	0.38	2.27	0.28

The results shown in Table 1 are consistent with the exergetic efficiencies obtained by Balomenos et al. 2011, which are 0.03 and 0.40 in the case of Bayer and Hall-Héroult process, respectively. It can be observed that, the exergetic efficiency of the Bayer process is significantly low, which indicates a poor use of the exergy present in the resources. The Hall-Héroult process shows a higher exergetic efficiency despite its high energy consumption. This difference can be attributed to the large destruction of exergy in the Bayer process.

There is a high relative increase in the exergoeconomic cost of the alumina in the Bayer process, due to a significant destruction of exergy in this process. Besides, the exergoeconomic factor suggests that fixed costs are low compared to total cost increase. This is due to high losses and exergy destruction in the Bayer and Hall-Héroult processes. These results leave opened the gate for designing a more expensive (higher fixed costs) but more efficient technology (lesser costs of waste and destruction of exergy) to produce aluminum. Modifications or incorporation of alternative processes should be considered in order to obtain higher exergetic efficiencies and a lower relative increases of the exergoeconomic costs. Since these modifications could lead to an increase in operating and investment costs, other analyses should be taken into account.

Although this approach showed important points to consider in order to increase the technical and economic performance of these processes, it does not quantitatively show which environmental improvements can be achieved, which is clearly observed when a LCA approach is carried out (Suciati, A., Goto, N. (2014); Tan et al. 2005). In this sense, the exergetic and thermoeconomic approach indicated by Querol et al. 2012 could be complemented by a LCA approach, which would quantify and highlight the environmental impact generated along with thermodynamic and economic indicators. In that sense, it is necessary to design a common methodology that has such purposes as has been pointed out other researches (Dincer and Rosen (2013); Kjelstrup et al. (2015); Zvolinschi et al. (2007); Liao et al. 2012), and also the analysis of different scenarios to observe the influence of alternative processes.

4| CONCLUSIONS

The application of an exergetic and thermoeconomic analysis to the typical aluminum production process showed that its exergetic losses are mainly due to the intrinsic characteristics of the reactions involved, which not only imply energy losses but also economic losses. Although the Hall-Héroult process consumes most of the energy used, Bayer process has the lower exergetic efficiency, which is also evident in the relative cost increase. The low value of the exergoeconomic factor in both processes indicates that alternative processes should be taken into account in order to increase their exergetic efficiencies. This exergetic and thermoeconomic approach allows to visualize the economic and energy losses due to exergy losses and destruction, which is neither clearly observed nor quantified through conventional methods. Although it could be inferred that a better exergoeconomic performance (high exergetic efficiency and low relative cost increase) would imply a lower environmental impact, it is imperative to carry out this study along with a LCA approach that shows it quantitatively. Hence, a common methodology that links both analyzes is required.

References

Balomenos E., Panias D., Paspaliaris I., (2011). Energy and Exergy Analysis of the Primary Aluminum Production Processes: A Review on Current and Future Sustainability. Mineral Processing and Extractive Metallurgy Review: An International Journal, 32:2, 69-89, DOI: 10.1080/08827508.2010.530721.

Dean J. A., (1998). Lange's Handbook of Chemistry. 15th Edition, McGraw-Hill Professional. ISBN-10 0-07016384-7.

Dincer I., Rosen M., (2013). Exergy: Energy, Environment and Sustainable Development. Elsevier Ltd. ISBN: 978-0-08-097089-9.

Gomes H. I., Mayes W. M., Rogerson M., Stewart D. I., Burke I. T., (2016). Alkaline residues and the environment: a review of impacts, management practices and opportunities. Journal of Cleaner Production, 112, 3571-3582. DOI: 10.1016/j.jclepro.2015.09.111

Husband C., McMahon G., Van der Veen P., (2009). The Aluminum Industry in West and Central Africa. Rec: http://siteresources.worldbank.org/EXTOGMC/Resources/336929-1266963339030/eifd13_wa_aluminum.pdf (Última visita MM-AAAA)

Kjelstrup S., Dewulf J., Norden B., (2015). A Thermodynamic Metric for Assessing Sustainable Use of Natural Resources, International Journal of Thermodynamics, Vol. 18 (No. 1) pages 66-72, ISSN 1301-9724, http://dx.doi.org/10.5541/ijot.5000086729

Lehoux, A.P., Lockwood, C.L., Mayes, W.M. et al. (2013). Gypsum addition to soils contaminated by red mud: implications for aluminium, arsenic, molybdenum and vanadium solubility. Environ Geochem Health 35: 643. DOI:10.1007/s10653-013-9547-6

Liao W., Heijungs R., Huppes G. (2012). Thermodynamic analysis of human–environment systems: A review focused on industrial ecology. Ecological Modelling, Volume 228, pages 76– 88, ISSN 0304-3800, http://dx.doi.org/10.1016/j.ecolmodel.2012.01.004

Querol E., Gonzalez-Regueral B., Pérez-Benedito J. L., (2012). Practical Approach to Exergy and Thermoeconomic Analyses of Industrial Processes. Springer-Verlag London.

Rusal, 2016. Aluminium production costs (2017). Available on: http://www.rusal.ru/en/aluminium/energetics/ (Last view: 02-2017)

Suciati, A., Goto, N., (2014). Environmental Impact Assessment of the Development of Primary Aluminum Industry in Indonesia based on MFA and LCA as a Baseline Study to Achieve Sustainable Industry. 3rd International Conference on Environment Energy and Biotechnology, DOI: 10.7763/IPCBEE. 2014. V70. 11

Tan R. B. H., Khoo H. H., (2005). An LCA study of a primary aluminum supply chain. Journal of Cleaner Production, 13,607-618. DOI: 10.1065/lca2004.08.172

Ter Weer PH., McCabe T., Lavignolle A., (2007). Capital cost: to be or not to be. TMS (The Minerals, Metals & Materials Society). Light Metal

Zvolinschi A., Kjelstrup S., Bolland, O., Van Der Kooi H. J., (2007). Exergy Sustainability Indicators as a Tool in Industrial Ecology. Journal of Industrial Ecology, 11: 85–98. DOI:10.1162/jiec.2007.1142.

DESAFIOS PARA REALIZAÇÃO DE UM ESTUDO DE AVALIAÇÃO DO CICLO DE VIDA ORGANIZACIONAL DO IBICT

CHALLENGES FOR AN ORGANIZATIONAL LIFE-CYCLE ASSESSMENT AT IBICT

Dr. Thiago Rodrigues*, Me. Tiago Braga*, Dr. Diogo Aparecido Lopes Silva**

* Instituto Brasileiro de Informação em Ciência e Tecnologia, SAUS 5, Bloco H, Sala 604, Brasília, Distrito Federal, Brasil, +55 61 3217 6286. E-mail: {thiagorodrigues, tiagobraga}@ibict.br
** Universidade Federal de São Carlos (UFSCar), Centro de Ciências em Gestão e Tecnologia, Departamento de Engenharia de Produção. Rodovia João Leme dos Santos, km110 – SP 264, Bairro do Itinga, Sorocaba, SP, Brasil. Phone: +55 3229-7454. E-mail: diogo.apls@ufscar.br

ABSTRACT:
This article discusses the major challenges for implementing Organizational Life-Cycle Assessment (OLCA) at the Brazilian Institute of Information in Science and Technology (IBICT). Traditional LCA studies are focused on products and services, easily quantifiable when compared with OLCA. However, there are some organizations that produce many physical goods and it becomes very complex to share their environmental impacts among their different outputs. So OLCA seeks to solve this problem. There is an ISO/TS 14072 standard launched in 2014, which defines a proper application of ISO 14040 and ISO 14044 to evaluate organizations as a whole. Other important initiative is the Organisation Environmental Footprint (OEF) that was developed to increase the efficient use of resources in the European context. Finally, the flagship project of UNEP/SETAC Life Cycle Initiative for LCA of Organizations, launched a guidance document which aims to facilitate the application of O-LCA. This document has undergone a road testing process to evaluate the usefulness of the method. By now, eight organizations from four different continents have been using the method. It seems that this method works well with companies that produce physical goods, however there is a lack of knowledge on the efficiency of its use on organizations working with intangible products, such as scientific information. This research will analyze the application of OLCA method at IBICT in order to identify the critical points and develop some guidance on doing OLCA on organizations dedicated to manage information.

Keywords:
Organizational Life-Cycle Assessment; Organizational Environmental Footprint; IBICT, functional unit.

RESUMO:
Este artigo discute os principais desafios na implementação de uma Avaliação do Ciclo de Vida Organizacional (ACV-O) do Instituto Brasileiro de Informação em Ciência e Tecnologia (IBICT). Estudos de ACV tradicionais estão focados em produtos e serviços, facilmente quantificáveis. No entanto, existem algumas organizações que produzem muitos bens físicos e torna-se muito complexo dividir seus impactos ambientais entre os diferentes produtos. A ACV-O procura resolver este problema. ACV-O já um método normalizado. A ISO/TS 14072, lançada em 2014, define a aplicação apropriada das normas ISO 14040 e ISO 14044 em organizações. Outra iniciativa importante é a pegada ambiental da organização (OEF em ilglês). Ela foi desenvolvida para aumentar o uso eficiente dos recursos no contexto europeu. Finalmente, a Iniciativa do Ciclo de Vida do Programa UNEP/SETAC LCA, lançou um documento de orientação que visa facilitar a implementação de ACV-O. Este documento foi submetido a um teste piloto para avaliar a viabilidade do método. Até agora, oito organizações de quatro continentes diferentes estão utilizando o documento. Há uma falta de conhecimento sobre a eficiência do ACV-O em organizações que trabalham com valores intangíveis como a informação científica. Esta pesquisa analisa a aplicação do método ACV-O ao IBICT para identificar pontos críticos e desenvolver orientações sobre a realização de ACV em organizações dedicadas à gestão da informação.

Palavras-chave:
Avaliação do Ciclo de Vida Organizacional; Pegada Ambiental de Organizações; IBICT; unidade funcional.

1| INTRODUÇÃO

A Avaliação do Ciclo de Vida (ACV) como metodologia para avaliação do desempenho ambiental de produtos já é aplicada pelas comunidades científica e empresarial envoltas com a questão ambiental. A produção científica, os congressos dedicados ao tema e os produtos com rotulagem ambiental tipo III são exemplos claros da estabilidade alcançada pela ACV focada em produtos. Apesar da definição de uma unidade funcional ser mais complexa do que pode parecer, quando o estudo está dirigido a um produto, em uma abordagem inicial, se pode simplesmente escolher uma unidade de massa (ou de energia) deste bem, como é o caso das abordagens cradle-to-gate (C2G) e gate-to-gate (G2G).

No entanto, há diversos sistemas de produto que em sua origem são multifuncionais. O estudo pode estar orientado sobre um produto específico, contudo, se ele é proveniente de um sistema que fabrica mais de um produto, a alocação se faz necessária ou a adoção dos métodos para evitá-la, quando aplicáveis (ISO, 2006) A alocação é um processo complexo e que pode gerar muitas incertezas, a própria norma indica que se evite sempre que possível.

Assim, outra abordagem se propõe para sistemas complexos, em que vários produtos são fabricados e que a alocação se torna inevitável e dificultosa. O foco volta-se para a organização como um todo. A Avaliação do Ciclo de Vida Organizacional, doravante tratada por ACV-O, é a alternativa metodológica desenvolvida para avaliar o desempenho ambiental de organizações segundo uma abordagem de ciclo de vida.

Segundo UNEP/SETAC (2015) alguns estudos com perspectiva de ciclo de vida em organizações foram realizados já na década de 1990. Finkbeiner et al (1998) discutiram a compatibilidade da ISO 14040 (focada em produtos) com a ISO 14001 (focada em organizações). Uma consequência desta preocupação foi a atualização da ISO 14001 em 2015 com a incorporação do ciclo de vida como questão estratégica nos sistemas de gestão ambiental das organizações (ISO, 2015). Outros estudos mais recentes de Huang et al (2009a, 2009b) trouxeram a análise de Input-output combinada com a perspectiva de ciclo de vida.

A ACV-O está normalizada desde 2014, com a implementação da norma ISO/TS 14072 (ISO, 2014). Trata-se de uma especificação técnica (TS na sigla em inglês) que estende a aplicação das normas ISO 14040 e 14044 para todas as atividades de uma organização.

Em paralelo à criação da norma ISO/TS 14072, outra iniciativa voltada à pegada ecológica de organizações foi desenvolvida. Com uma perspectiva também de ciclo de vida, o guia da Pegada Ambiental de Organizações (OEF na sigla em inglês) é produto de uma iniciativa da Comissão Europeia para a Estratégia 2020 – Roteiro para uma Europa eficiente no uso de recursos (tradução do autor) (EC, 2012).

A última contribuição metodológica expressiva para a avaliação ambiental de organizações é o guia Orientação sobre ACV Organizacional, produção conjunta da Iniciativa para o Ciclo de Vida do Programa Ambiental das Nações Unidas (UNEP) e da Sociedade para Química e Toxicologia Ambiental (SETAC) (UNEP/SETAC, 2015). O documento busca criar consistência e credibilidade e facilitar a aplicação da ACV-O.

As organizações são muito diversas, com áreas de atuação completamente distintas. Este fato provoca abordagens de ciclo de vida customizadas, mas sem desrespeitar os protocolos normativos. Uma organização que produz bens físicos deverá ser avaliada de forma diferente de uma organização que presta serviços, por exemplo.

Neste contexto, esta pesquisa tem como objetivo discutir os principais desafios para realizar a ACV-O do Instituto Brasileiro de Informação em Ciência e Tecnologia – IBICT.

2| METODOLOGIA

Esta pesquisa se desenvolveu sobre a análise das normas, manuais e guias disponíveis para a realização de uma ACV-O de uma organização que gera produtos, em sua maioria, intangíveis como é o produto informação tecnológica. Trata-se de um estudo de caso aplicado ao Instituto Brasileiro de Informação em Ciência e Tecnologia – IBICT.

2.1. Compatibilização dos conceitos de organização

Primeiramente buscou-se compreender o significado de organização através de conceitos clássicos provenientes da literatura específica ao tema, assim como o conceito definido pelas normas e guias dedicados ao ACV-O. Uma etapa importante foi verificar se há qualquer distinção evidente entre os conceitos clássicos e os relacionados com a perspectiva do ciclo de vida.

2.2. Diagnóstico organizacional do IBICT

O IBICT é uma instituição pública, submetida ao Ministério de Ciência, Tecnologia, Informação e Comunicação (MCTIC) que atua fundamentalmente na gestão da informação científica e tecnológica. A missão do IBICT prevê ações ligadas à capacitação, recursos e gestão da informação tecnológica (IBICT, 2017). A instituição tem sede em Brasília e uma seção voltada ao ensino e pesquisa no Rio de Janeiro. A estrutura organizacional do IBICT é composta por várias coordenações e algumas divisões. Os produtos do IBICT são em sua maioria publicações de documentos técnicos, sistemas de gestão da informação tecnológica, portais especializados em ciência e tecnologia, além do serviço de ensino e pesquisa. As categorias de produtos foram definidas a partir da análise da carta de serviços do instituto, disponível no site. Esta característica de multiplicidade de produtos intangíveis faz da ACV-O a mais adequada para avaliar o desempenho ambiental da instituição.

2.3. Adequação do IBICT à norma ISO/TS 14072

A compreensão da estrutura organizacional do IBICT permitiu a verificação de como a instituição IBICT se adéqua aos conceitos analisados, por meio da análise da sua missão, estrutura organizacional, atuação e produtos gerados. Esta verificação foi orientada para possibilitar a definição de objetivo e escopo de um estudo ACV-O do instituto e, mais especificamente, compreender como definir uma unidade funcional. Ao final, a pesquisa pretendeu identificar quais são os pontos críticos à realização de um estudo ACV-O do IBICT e discuti-los.

3| RESULTADOS E DISCUSSÕES

3.1. Conceitos de organização e normas para ACV-O

Uma organização é um sistema intencional de associação humana que utiliza recursos em prol de objetivos (Lacombe, 2003; Maximiano, 2008). Há dois componentes básicos nas organizações para alcançar seus objetivos: divisão do trabalho e processos de transformação (Maximiano, 2008). Os processos de transformação convertem os recursos em produtos e como consequência geram os impactos ambientais.

A norma ISO/TS 14072 (2014) define organização também como um grupo humano, com funções e responsabilidades para atingir seus objetivos. Ela ainda apresenta uma série não excludente de tipos de organizações. Segundo a TS, a metodologia é aplicável a qualquer tipo de organização.

O guia OEF orienta sobre as fases de um estudo de pegada ambiental e não se preocupa em conceituar organizações, mas promove a criação de regras específicas para os setores nas quais cada organização atua (OEFSR na sigla em inglês). A ideia central destas regras é focar nos aspectos mais relevantes de cada setor para incrementar a relevância, reprodutibilidade e consistência de um estudo OEF (UNEP/SETAC, 2015).

O guia UNEP-SETAC está fortemente alinhado à ISO/TS 14072 e provê mais detalhes na aplicação da norma. A iniciativa conjunta, além de lançar o guia, está promovendo a sua aplicação, através de um teste com organizações de várias partes do mundo (Life Cycle Initiative, 2017). No momento, oito organizações já realizaram a ACV-O e os estudos estão em processo de validação, mais cinco organizações ingressaram no teste e estão nas fases iniciais. Entre todas as organizações presentes no teste, três (um banco, uma prefeitura e uma faculdade) atuam na área de serviços.

Finkbeiner e König (2013) analisaram a adaptação da ISO 14044 de produtos para organizações. Eles observaram que a maior parte dos requisitos são diretamente aplicáveis para organizações. A definição das fronteiras do sistema e os procedimentos de alocação são parcialmente aplicáveis, enquanto que a comparação entre sistemas com a mesma função não deve ser realizada.

3.2. Diagnóstico organizacional do IBICT

A tabela 1 resume o diagnóstico organizacional do IBICT, contemplando a missão, a estrutura organizacional e os principais produtos disponibilizados pela instituição. Tal diagnóstico foi realizado através da consulta ao site do instituto.

Tabela 1 – Missão e estrutura organizacional do IBICT.
Table 1 – Mission and organizational structure of IBICT.

ORGANIZAÇÃO					
Instituto Brasileiro de Informação em Ciência e Tecnologia - IBICT					
UNIDADES					
2	Brasília e Rio de Janeiro				
MISSÃO					
Promover a competência, o desenvolvimento de recursos e a infraestrutura de informação em ciência e tecnologia para a produção, socialização e integração do conhecimento científico e tecnológico.					
ESTRUTURA ORGANIZACIONAL					
Diretoria	Conselho técnico-científico	Coordenações	Divisões	Setores	
		13	12	2	
PRODUTOS					
Bibliotecas e Repositórios	Redes e Portais	Ensino e Pesquisa	Sistemas e softwares	Projetos e Serviços	Publicações
4	12	2	9	4	4

A estrutura organizacional do IBICT é bastante formal, com uma hierarquia evidente e os produtos bastante setorizados. Há um conjunto com 42 produtos e serviços segundo a carta de serviços disponível no site do instituto (IBICT, 2017). Ainda é possível identificar "subprodutos" dentro dos grupos de produtos apresentados na tabela 1. No caso das redes e portais, em cada um há ainda uma série de produtos disponibilizados, como é o caso do portal da ACV, onde se encontram cartilhas, livros, apostila de cursos, acesso ao banco nacional de ICV (SICV Brasil) (ACV IBICT, 2017). O fato é que os produtos disponíveis são integralmente intangíveis e sem fim de vida definido.

Uma primeira dificuldade a ser enfrentada por um estudo ACV-O do IBICT é a definição das fronteiras do sistema, conforme destacado no trabalho de Martinez et al (2015). Os limites de atuação e influência de uma instituição que trabalha majoritariamente com produtos intangíveis (informação) são difíceis de traçar e estabelecer, pois não há um fim de vida para estes. Neste sentido, uma abordagem cradle-to-gate é a mais indicada, embora ainda haja dificuldades para delimitar os fornecedores de matéria-prima e insumos, além dos recursos físicos (água, eletricidade, etc.) necessários ao funcionamento operacional da organização.

A ISO/TS 14072 determina a definição do reporting flow, o equivalente ao fluxo de referência de uma ACV orientada ao produto. Trata-se da quantidade referencial do portfólio da organização, à qual todo o inventário está relacionado. Em companhias que produzem bens físicos o reporting flow pode ser definido pela quantidade em unidades do produto ou em massa ou em volume. No entanto, para o caso de instituições que proveem serviços, a norma indica a definição do reporting flow em termos econômicos ou número de funcionários. No caso do IBICT, a referência econômica não serve, visto que se trata de uma instituição pública que não vende produtos, mas os disponibiliza gratuitamente à sociedade. O número de funcionários pode ser uma alternativa razoavelmente fácil de contabilizar, diante da impossibilidade de outras opções.

A fase de inventário de organizações não difere tanto de produtos, sendo o sistema dividido em atividades/processos diretos e indiretos (cadeia de valor). Da mesma forma que a definição das fronteiras, a dificuldade maior para uma instituição como o IBICT é o levantamento de dados dos processos indiretos. Os processos downstream não são mensuráveis de maneira óbvia, os serviços oferecidos pelo IBICT não têm um fim de vida, são de uso contínuo desde que o instituto os mantenha disponível. Mais uma vez, a indicação é pela abordagem cradle-to-gate. A figura 1 ilustra a proposta de abordagem.

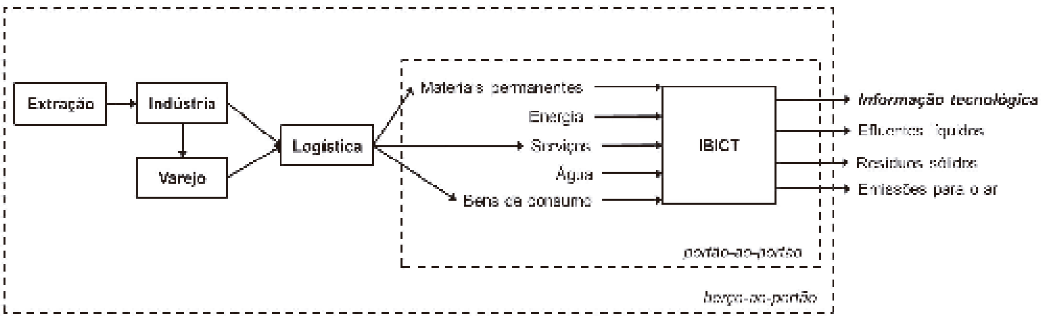


Figura 1 – Fluxograma geral da organização IBICT com duas abordagens possíveis de ciclo de vida.

Figure 1 – General flowchart of IBICT as an organization with two possible life-cycle approaches.

A questão da multifuncionalidade também deve ser enfrentada na ACV-O do IBICT. O instituto tem um portfólio bastante distinto, principalmente pelo fato da unidade do Rio de Janeiro atuar na área de ensino. Neste caso, uma alternativa viável pode ser a realização do estudo ACV-O regionalizado (unidade de Brasília e unidade do Rio de Janeiro).

4| CONCLUSÕES

A pesquisa identificou os principais pontos críticos à realização de estudo ACV-O do IBICT. A análise das normas mostrou que não há diferença significativa entre os conceitos de organização. Os resultados evidenciaram a dificuldade de implementação de estudos de ACV-O para organizações que geram produtos intangíveis, como é o caso do IBICT, que atua essencialmente com gestão da informação tecnológica. Os pontos críticos que um estudo ACV-O do IBICT teria estão todos relacionados às fases iniciais do estudo: definição de objetivo e escopo e inventário. A definição de fronteiras não é óbvia, principalmente devido aos processos downstream. Os mesmos processos afetam a construção do inventário. Como observado nas discussões, a definição do reporting flow é uma tarefa complicada para organizações com produtos intangíveis como o IBICT. A multifuncionalidade é uma característica do IBICT que pode ser evitada pela abordagem regionalizada das unidades que compõem o instituto.

Referências

ACV-IBICT – Projeto de Avaliação do Ciclo de Vida do Instituto Brasileiro de Informação em Ciência e Tecnologia. Acesso: http://acv.ibict.br/

EC – European Commission – Joint Research Centre – Institute for Environment and Sustainability. 2012. Organisation Environmental Footprint (OEF) Guide. JRC: Ispra.. 148 p. Disponível em: http://ec.europa.eu/environment/eussd/pdf/footprint/OEF%20Guide_final_July%202012_clean%20version.pdf

Finkbeiner M., Konig P., 2013. Carbon Footprint and Life Cycle Assessment of Organizations. Journal of Environmental Accounting and Management, 1(1), 55–63.

Finkbeiner M., Wiedemann M., Saur K., 1998. A comprehensive approach towards product and organisation related environmental management tools. The International Journal of Life Cycle Assessment, 3(3), 169–178.

Huang Y.A., Lenzen M., Weber C.L., Murray J., Matthews H.S., 2009a. The role of input-output analysis for the screening of corporate carbon footprints. Economic Systems Research, 21(3), 217–242.

Huang Y.A., Weber C.L., Matthews H.S., 2009b. Categorization of scope 3 emissions for streamlined enterprise carbon footprinting. Environmental Science & Technology, 43(22), 8509–8515.

IBICT – Instituto Brasileiro de Informação em Ciência e Tecnologia. 2017. Carta ao cidadão – carta de serviços ao cidadão. Disponível em: http://www.ibict.br/Carta-de-servicos-ao-cidadao/servicos-prestados-pelo-ibict

ISO 2006. ISO 14044: Environmental Management — Life Cycle Assessment — Requirements and Guidelines. Geneva, Switzerland: International Organization for Standardization.

ISO 2014. ISO/TS 14072. Environmental management — Life cycle assessment — Requirements and guidelines for Organizational Life Cycle Assessment. Geneva, Switzerland: International Organization for Standardization.

ISO 2015. ABNT/NBR ISO 14001. Sistemas de gestão ambiental — Requisitos com orientações para uso ABNT/CB-038 Gestão Ambiental 41 p.

Lacombe, F. J.; Heilborn, G. L. J., 2003. Administração – Princípios e tendências. São Paulo: Saraiva. 560 p.

Martinez-Blanco, J.; Inaba, A.; Finkbeiner, M., 2015. Scoping organizational LCA – challenges and solutions. International Journal of Life Cycle Assessment. Vol. 20 (4). 14 p.

Life Cycle Initiative – UNEP/SETAC. LCA of Organizations (Flagship 1C). Acesso: http://www.lifecycleinitiative.org/activities/phase-iii/lca-in-organisations/

Maximiniano, A. C. A. 2008. Introdução à Administração. Atlas: São Paulo. 404 p.

UNEP/SETAC – Guidance on Organizational Life Cycle Assessment. UNEP: Paris. 2015. 152 p. Disponível em: http://www.lifecycleinitiative.org/o-lca-guidance-launched/

Assessing the food bioeconomy by Green Protein Footprint: a case study of the seafood sector

Dr. Isabel García*, PhD. Jara Laso*, Dr. María Margallo*, Ing. María Serrano*, Dr. Ian Vázquez-Rowe, Dr. Angel Avadí***, Dr. Pére Fullana****, Dr. Alba Bala****, Dr. Cristina Gazulla*****, Prof. Ángel Irabien*, Dr. Rubén Aldaco***

* Department of Chemical and Biomolecular Engineering, University of Cantabria, Avda. de los Castros s/n, 39005, Santander, Spain. E-mail: jara.laso@unican.es
** Peruvian LCA Network, Department of Engineering, Pontificia Universidad Católica del Perú, Av. Universitaria 1801, San Miguel, Lima, Perú. Email: ian.vazquez@pucp.pe
***CIRAD, UPR Recyclage et risqué, F-34398 Montpellier, France
****UNESCO Chair in Life Cycle and Climate Change, Escola Superior de Comerç International (ESCI-UPF). Pg. Pujades 1, 08003, Barcelona, Spain
*****Lavola Cosostenibilidad. Rbla. Catalunya 6, 08007, Barcelona, Spain

ABSTRACT:
The main advantage that human population acquire from fisheries is the protein supply, which constitutes an essential part of the human diets. However, wasting seafood involves the loss of nutrients along the food supply chain and causes environmental impact. To promote the Bioeconomy in the food sector, it is necessary to evaluate the relationship between the consumption and the production of food products from a nutritional and environmental point of view. This work develops a methodology to determine the Green Protein Footprint (GPF) of food products in order to assess its protein content and environmental impact. The GPF indicator can be applied to all food chain products; however, this case study is focused on seafood products, in particular, on anchovy products. European anchovy can be consumed fresh, salted and canned. Regarding the latter, several organic wastes are generated in the offal, heading and cutting processes. These residues can be collected to produce fishmeal for their use in aquaculture, feeding to other fish species which are consumed by human population. This allows turning waste into a resource as part of "closing the loop" in a circular economy system.

Keywords:
Bioeconomy; Engraulis encrasicolus; environmental impact; fish protein; Green Protein Footprint.

1| INTRODUCTION

About 800 million people around the world are suffering from chronic undernourishment, while each year approximately 1.3 billion metric ton of edible food are wasted throughout global food supply chain (FAO, 2014). Moreover, this amount of wasting food produces the emission of 3.3 Gt CO2 eq. (Corrado et al. 2017). In addition to cause environmental impact, food contributes to consumers with nutritional value, mainly through its protein content, and wasting food involves the loss of these nutrients along the food supply chain.
In this sense, the European Commission is dealing with natural resources scarcity, climate change and population growth by means of a series of environmental and nutritional policies, such as the Bioeconomy Strategy (European Commission, 2012) and the Food and Nutrition Security Strategy (European Commission, 2016).
This work develops a methodology to obtain a sustainable index, the Green Protein Footprint (GPF), which combines all the concepts covered by the European policies. The GPF assesses and compares both the environmental impact of a food product and the protein contain provided to consumers in order to simplify the decision making process.
This methodology can be applied to all food chain products; however, this work is focused on anchovy products. In the canning anchovy sector, considerable amounts of fish residues are generated, on both the production of canned and salted anchovies. These food losses are a source of nutrients that could be valorized to produce feed for aquaculture.

2| METHODOLOGY

Figure 1 displays the methodology followed in this work to obtain the GPF index. Firstly, Life Cycle Assessment (LCA) methodology was used to assess the environmental impacts linked to the production and consumption of anchovy products. Then, the Life Cycle Protein Assessment (LCPA) was performed to calculate the Protein Footprint (PF) of each product based on the protein content of the anchovy, as well as the ingredients among their life cycle. To conduct a comparison of scenarios the extraction of fresh anchovy as a resource by purse seine vessels from Cantabria was taken as reference.

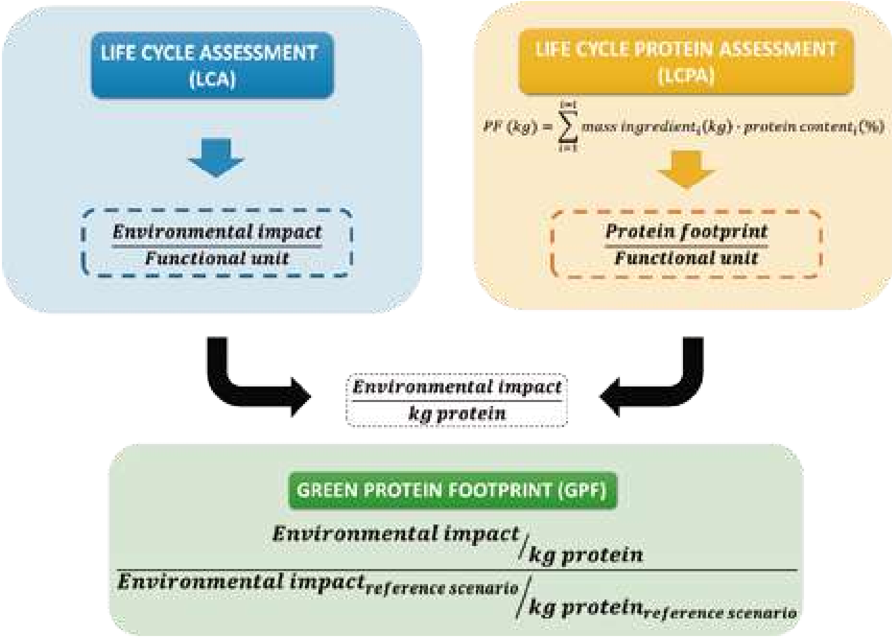


Figure 1. Green Protein Footprint (GPF) methodology.

2.1. Life Cycle Assessment (LCA)

2.1.1 Goal and scope

The anchovy industry in Cantabria (Northern Spain) is based on three main products for direct human consumption (DHC): fresh, salted and canned anchovies in olive oil. Contrary to the Peruvian anchoveta fishery, in which almost 100 % of captured anchovies are reduced to fishmeal (Avadí et al. 2014). The goal of the present study is to develop a methodology by means of the joint computation of environmental and nutritional indicators in order to attain the GPF for European anchovy products. According to other canned seafood products studies (Iribarren et al. 2010; Hospido et al. 2006), the functional unit (FU) was 1 kg of European anchovy processed and consumed in Cantabria Region.

The analyzed scenarios were: (i) production of fishmeal from anchovy and its use as feed in aquaculture; (ii) fried anchovies dipped in flour; (iii) rolled in batter anchovies; (iii) anchovies in vinaigrette; (iv) salted anchovies and (v) canned anchovies in olive oil. In case of salted and canned anchovies in olive oil, high amounts of anchovy residues were generated which were valorized into fishmeal and used in bass aquaculture. Hence, humans are finally consuming fish protein from the residues linked to the production of salted and canned European anchovy, closing the loop of the product life cycle.

2.1.2 Life cycle inventory and data acquisition

Data on the assessment of anchovy fishery, and salted and canned anchovies were mainly primary data taken from previous studies (Laso et al. 2017; 2016). For the remaining scenarios, data were retrieved from bibliographical sources.

2.1.3 Life cycle impact assessment

The Life cycle impact assessment was conducted with the LCA software Gabi 6.0 (PE International, 2014) and using the ReCIPE endpoint method (Goedkoop et al. 2009). This method compiles 18 impact categories in three different areas of protection: human health, resources availability and ecosystem diversity in one single score, facilitating the decision making process. A hierarchist perspective was selected because it considers the main policy approaches linked to time horizons (i.e. 100-year horizon for global warming) (Lorenzo-Toja et al. 2016).

2.2. Life cycle protein assessment (LCPA)

This section shows the protein balance of European anchovy products through its life cycle based on their protein content. The edible meat fraction and the protein content of European anchovy were 62 % and 21 %, respectively (Peter Tyedmers, personal communication). The protein content of the rest of ingredients was obtained from the Self-Nutrition Data database (Self-Nutrition Data, 2014)

3| RESULTS AND DISCUSSION

Table 1 shows the environmental impact based on the single score indicator, the protein footprint and the dimensionless index GPF for each scenario. Even though the single score of the ReCIPE endpoint methodology provides an overall picture of the environmental, the results should be interpreted with caution, taking into account the higher uncertainty within the methodology (Lorenzo-Toja et al. 2016). The reference value for normalization was that corresponding to the anchovy fishing. The production of fishmeal for trout aquaculture presented the highest GPF (6.42) followed by the salted anchovies (5.13), whereas the fried anchovies dipped in flour had the lowest GPF (1.45) followed by the anchovies in vinaigrette. The use of circular economy in valorization of anchovy residues is reflected in the low GPF value of the canned anchovies in olive oil (2.61).

Anchovy products	Single Score (mPt)	Protein footprint (g)	GPF
Anchovy fishing (reference scenario)	174.0	210.0	
Fishmeal	265.6	49.95	6.417
Fried anchovies dipped in flour	231.2	191.8	1.455
Rolled in batter anchovies	428.6	219.1	2.361
Anchovies in vinaigrette	223.6	168.6	1.601
Salted anchovies	802.8	188.7	5.135
Canned anchovies in olive oil	235.8	108.9	2.613

Table 1. Green Protein Footprint (GPF) for each anchovy products.

4| CONCLUSIONS (AND OPTIONALLY RECOMMENDATIONS)

This paper combines two terms that are of vital importance to our global population: environmental impact and nutrition, developing a new sustainable index, the Green Protein Footprint (GPF) which assesses and compares both the environmental impact of a food product and the protein content provided to consumers. From this work we have identified that food products the more elaborated products, the higher environmental impact and GPF. Moreover, the food losses among the life cycle reduced the protein content of the product. The product selection and cooking methods are identified as highly variables. Therefore, the GPF facilitates de decision making process to consumers and producers.

Acknowledgements (optional)

The authors thank the Ministry of Economy and Competitiveness of the Spanish Government for their financial support via the projects GeSAC-Conserva: Sustainable Management of the Cantabrian Anchovies (CTM2013-43539-R) and CERES_Project: Food Production strategies for climate change mitigation: towards a food circular economy (CTM 2016-76176-C2-1-R). Jara Laso thanks the Ministry of Economy and Competitiveness of Spanish Government for their financial support via the research fellowship BES-2014-069368.

References

Avadí, A., Fréon, P., Quispe, I., 2014. Environmental assessment of Peruvian anchoveta food products: is less refined better? Int. J. Life Cycle Assess. 19, 1276-1293.

Corrado, S., Ardente, F., Sala, S., Saouter, E., 2017. Modelling of food loss within life cycle assessment: from current practice towards a systematization. J. Clean Prod. 140 (2), 847-859.

European Commissions (EC), 2012. The Bioeconomy Strategy. Available at: http://ec.europa.eu/research/bioeconomy/index.cfm?pg=policy&lib=strategy.

European Commission (EC), 2016. Available at: http://ec.europa.eu/europeaid/sectors/food-and-agriculture/food-and-nutrition-security_en.

FAO, 2014. The State of Food Insecurity in the World.

Goedkoop, M., Heijungs, R., Huijbregts, M., Schryver, A., Struijis, J., Van Zelm, R. 2009. ReCIPE 2008. A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint.

Hospido, A., Vazquez, M.E., Cuevas, A., Feijoo, G., Moreira, M.T., 2006. Environmental assessment of canned tuna manufacture with a life-cycle perspective. Resour. Conserv. Recy. 47, 56-72.

Iribarren, D., Moreira, M.T., Feijoo, G., 2010. Life Cycle Assessment of fresh and canned mussel processing and consumption in Galicia (NW Spain). Resour. Conserv. Recy. 55, 106-117.

Laso, J., Margallo, M., Fullana, P., Bala, A., Gazulla, C., Irabien, A., Aldaco, R., 2016. Introducing life cycle thinking to define best available techniques for products: Application to the anchovy canning industry. J. Clean Prod. (In press) DOI: 10.1016/j.jclepro.2016.08.040.

Laso, J., Margallo, M., Fullana, P., Bala, A., Gazulla, C., Irabien, A., Aldaco, R., 2017. When product diversification influences life cycle impact assessment: a case study of canned anchovy. Sci. Tot. Environ. 581-582, 629-639.

Lorenzo-Toja, Y., Vázquez-Rowe, I., Amores, M.J., Termes-Rifé, M., Marín-Navarro, D., Moreira, M.T., Feijoo, G., 2016. Benchmarking wastewater treatment plants under an eco-efficiency perspective. Sci. Total Environ. 566-567:468-479.

PE International, 2014. Gabi 6 Software and Database on Life Cycle Assessment. Leinfelden-Echterdingen (Germany).

Shelf Nutrition Data, 2014. Available at: http://nutritiondata.self.com/topics/processing.

Life Cycle Assessment of Paddy in Lambayeque, Peru

MSc. Isabel Quispe*,, PhD. Rodrigo Navia**,***,****, PhD. Ramzy Kahhat***

* Pontificia Universidad Católica del Perú, Department of Engineering, Peruvian LCA Network, Avenida Universitaria 1801, San Miguel, Lima 32, Peru
** University of La Frontera, Scientific and Technological Bioresources Nucleus, P.O. Box 54-D, Temuco, Chile
*** University of La Frontera, Department of Chemical Engineering, P.O. Box 54-D, Temuco, Chile4
**** Centre for Biotechnology & Bioengineering (CeBiB), University of La Frontera, P.O. Box 54-D, Temuco, Chile.

ABSTRACT:
The paddy production in Peru is focused at the North of Peru concentrating the 73% of national production where Lambayeque has a big share with an average yield of 9.5 t/ha. At the moment, 85% of rice husk is burned at open air or is disposal into rivers, contaminating our environment and 15% is used in farms as "poultry litter". The paddy is obtained from the agricultural phase which is divided in three stages: seedling, crop in definitive field and harvest which are described to obtain 1 ton of paddy (rice with husk). Additionally, paddy is cultivated in flooded soils consuming 1,200 M3 per ton of paddy, the fertilizer more consumed is urea followed by Ammonium Sulfate and Diammonium phosphate, having a total consumption of 120 kg. of fertilizers per ton of paddy. Finally, according to the impact categories global warming potential, acidification, and eutrophication, the environmental impacts were calculated.

Keywords:
Life Cycle Assessment, Paddy, Peru, Agricultural residue

1| INTRODUCTION

Current environmental problems have different causes including global warming due to emissions of green-house gases (GHGs) which are generated mainly by burning fossil fuels such as diesel, gasoline and coal (Report2007-IPCC). On the other hand, all deposits of fossil fuels take millions of years to accumulate while the deposits are extracted rapidly, and if the extraction rate is faster than the replenishment rate the resource will be finite in the sense that it will eventually be depleted (Höök and Pang, 2013; Capellán-Pérez et al., 2014). Facing this reality, governments have proposed policies to change their energy matrix in order to increase the share of renewable sources to 15% and in some cases reach 30% (Gabrielle et al., 2014).In this regard, researches have aimed at obtaining energy from available biomass including solid agricultural residues which can be used for direct combustion to generate energy.

Agricultural residues are generated in large amounts and are renewable energy resources that would provide about 10% of the total energy (Okeh et al., 2014), thus becoming an important alternative energy for the consumption of fossil fuels.
The use of biomass offers numerous advantages such as the mitigation of hazardous emissions such as CO2, NOx, CH4, SOx and CO, due to low amount of S and N contained on agricultural residues, and also the amount of Cl is minimum on such residues. Another advantage is the diversification of fuel supply, it will prevent the depletion of non-renewable resources. Furthermore, agricultural residues have lower costs than fossil fuels.
However, if the use of agricultural residues to obtain energy were to be promoted by governments, it would be necessary to do an integral assessment taking into account all the stages of its life cycle, and comparing it with the use of fossil fuels to identify under what conditions and scenarios it actually there is a less impact.
In the Peruvian case study, 16'000,000 metric tons of agricultural waste are generated annually. The rice husk has an important share in agricultural residues reaching an amount of 608,600 tons per year. The paddy production is located mainly at the North of Peru with a share of 73%.
On the other hand, the Peruvian energy policy is promoting the use of renewable energy from agricultural residues, but there is not enough information adapted to the current situation to decide on what resource and technology should be used and under what conditions. Thus, the purpose of this first study is to perform an environmental assessment for obtaining 1 tonne of paddy in Peru, using life cycle assessment as a methodology to foster sustainability.

2| METHODOLOGY

Life cycle assessment (LCA) is an international standardized methodology to identify and quantify the environmental impacts at every stage of the life cycle, from obtaining resources and materials, production, distribution, using to final disposal of the same (ISO, 2006). According to international standard ISO 14040, an LCA is an iterative cycle of knowledge and optimization comprising the steps: objective and scope, inventory, environmental impacts evaluation and interpretation, where their interaction and the direct application of the results are analyzed.

2.1. Objective and scope of the study

The objective of this study is to identify and to quantify the environmental impacts of obtaining one tonne of paddy to help decision making in the paddy production sector contributing this way to sustainability.
The scope of this study is the agricultural phase and the functional unit used was 1 tonne of paddy. The primary source of information for the data collection on the selected location (Lambayeque) comes from interviews to farmers, technical professional people and representatives of farmers associations. Also, secondary sources of information were used such as papers and reports to obtain data of the activities performed at the other places different to selected location.
The scope of the study to evaluate the environmental impacts have been from seedling stage to harvest stage including the production of fertilizers, pesticides, and herbicides as well as the production of diesel.
For the LCA study, the SIMAPRO 8.2.0.0 software was used as the main informatics tool and the ecoinvent® v3.1 database which has well-documented information about 4,000 processes.

2.2. Inventory

The agricultural phase has three stages: seedling, crop in definitive field and harvest (Abril et al., 2009; Orbegoso and Prado, 2013). The seedling yield is 1:20, for instance, one hectare of seedling yields twenty hectares of crop in definitive field. The paddy campaign is once per year because of the limited availability of water in the Peruvian coast, the seeding is from January to March and the harvest is from May to August.
According to interviews and literature (Orbegoso and Prado, 2013; Heros, 2013; Bruzzone and Heros, 2011) the consumed resources in the agricultural phase are diesel, seed, water, fertilizers, herbicides and pesticides. To prepare the land is necessary to use three kinds of similar machines that consume diesel to operate.
Seeds are bought from two seedbeds located in the study area, these are certificated seeds and the most used of them are: IR43 and Tinajones. All the fertilizers, herbicides and pesticides are generally imported from Russia and China. On the other hand, the average yield of paddy has reached 9.5 t/ha because of the improving of the agronomic handling.
The majority of the farmers (90%) performs mechanized harvest, the harvest machines are known as “combinada” and are usually rented because in the Peruvian Coast there is a campaign per year, but this situation could cause pest problems if there is not a good maintenance of the machines.
The consumptions of materials and fuel for the stages of seedling, crop in definitive field and harvest to obtain one tonne of paddy are shown in Table 1.

Table 1. Consumed resources for one tonne of paddy

	Unit	Seedling	Crop in definitive field	Harvest
Diesel	l	0.379	8.766	3.188
Water	m3	9.50	1452.7	
Seed	kg	8.42	-	
Fertilizers				
Urea	kg	4.38	44.62	
Ammonium Sulfate	kg	2.92	32.58	
Diammonium phosphate	kg	0.58	22.88	
Potassium Sulfate	kg	-	21.05	
Herbicide	kg	0.29	0.19	
Pesticide	kg	0.04	0.08	

The consumed amount of water, pesticides, herbicides and fertilizers per tonne of paddy in the seedling stage are lower than the consumed amount in the definitive field crop stage because of seedling yield.
The total consumption of fertilizers is of 129 kg per ton of paddy.The most consumed fertilizer is urea followed by Ammonium Sulfate and Diammonium phosphate.
The models to calculate the emissions in the crop fields by using fertilizers as well as the emitted quantities are shown in Table 2.

Table 2. Models and quantity of direct field emissions

Emission	Quantity (kg/tonne paddy)	Model
Ammonia (NH_3)	5.07	EMEP (EEA 2013) or EMEP (EEA 2006)
Nitrous oxide (N_2O)	1.12	IPCC 2006 - crops
Nitrogen oxides (NO_X)	1.92	EEA 2013
Carbon dioxide (CO_2)	35.93	IPCC 2006 - crops
Methane (CH_4)	7.90	IPCC 2006 - crops
Nitrate (NO_3^-)	32.21	SALCA - NO_3 SQCB
Phosphorus (P)	0.052	SALCA– P (Prasuhn 2006)

3| RESULTS AND DISCUSSION

The results of the inventory (LCI) were analyzed in order to calculate the environmental impacts for each impact category. The impact categories considered for the impact assessment of this study were: global warming, eutrophication and acidification.
The emissions to produce one tonne of paddy reach up to 718.7 kg.CO2-eq, 10.4 kg. SO2-eq and 5.9 kg. PO-34-eq according to the impact categories global warming potential, eutrophication and acidification, respectively. These impacts are mainly generated in the stage of crop in definitive field; the production and emissions of fertilizers contribute to 90% of the environmental impacts.
Subsequently, environmental impacts were calculated by varying crop yields, of 8.5 t/ha, 9.5 t/ha y 10.5 t/ha. The results are shown in Figure 2.

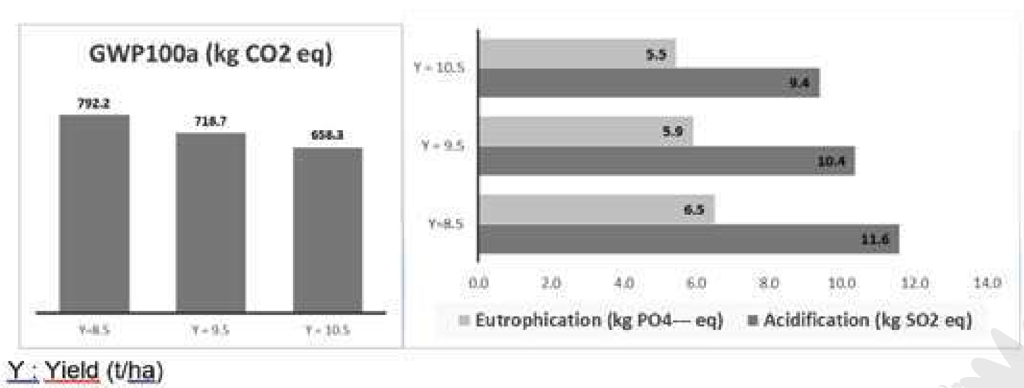


Figure 2. Environmental impacts according to the impact categories

4| CONCLUSIONS

Paddy is cultivated in flooded soils consuming 1,463 m3 of water per ton of paddy. Taking into account that in the Peruvian coast the rain is minimum the major difficulty to cultivate rice is the insufficient water supply.
According to the global warming category, one ton of paddy emits 718.7 kg of CO_2eq, 10.4 kg of SO_2-eq and 5.9 kg of PO_4^{3-}-eq of which 90% of the mentioned emissions are generated by the crop in definitive field stage due to the production and emissions of fertilizers.
If the crop yield increase, the environmental impacts decrease in 10% or 16% because of the improvement in agronomic handling.
The results of this study will help to calculate the environmental impacts of rice (as food) and rice husk (as energy source).

Acknowledgements

Authors would like to thank the Ph.D. Program in Sciences of Natural Resources and the Scientific and Technological Bioresources Nucleus at the University of La Frontera, Temuco, Chile, as well as the Department of Engineering at the Pontificia Universidad Católica del Perú (PUCP), Lima, Peru.

References

Abril D, Navarro E, Abril A. La paja de arroz. Consecuencias de su manejo y alternativas de aprovechamiento. Agronomía. 2009;17(2):69-79.
Bruzzone, C., Heros, E., 2011. Manejo integrado en producción de arroz y saneamiento. Piura, Peru.
Capellán-Pérez, I., Mediavilla, M., de Castro, C., Carpintero, O., Miguel, L.J., 2014. Fossil fuel depletion and socio-economic scenarios: An integrated approach.
Energy. 77, 641-666.
Gabrielle, B., Bamière, L., Caldes, N., DeCara, S., Decocq, G., Ferchaud, F., Loyce, C., Pelzer, E., Perez, Y., Wohlfahrt, J., Richard, G., 2014. Paving the way for sustainable bioenergy in Europe: Technological options and research avenues for large-scale biomass feedstock supply. Renewable and Sustainable Energy Reviews. 33, 11–25.
Heros, E., 2013. Manejo integrado del cultivo arroz. San Martin, Peru.
Höök, M., Pang, X., 2013. Depletion of fossil fuels and anthropogenic climate change-A review. Energy Policy. 52, 797–809.
Intergovernmental Panel on Climate Change (IPCC), 2007. Climate change 2007 the physical science basis. In: Solomon, S., Qin, D., Manning, M., Marquis, M., Averyt, K., Tignor, M.M.B., Henry Le Roy Miller, J. (Editors.), Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge,p.212.
International Standard Organization. (2006). ISO 14040 - Environmental Management - Life Cycle Assessment - Principles and Framework.
Nemecek T., Bengoa X., Lansche J., Mouron P., Riedener E., Rossi V. & Humbert
S. (2015) Methodological Guidelines for the Life Cycle Inventory of Agricultural Products. Version 3.0, July 2015. World Food LCA Database (WFLDB). Quantis and Agroscope, Lausanne and Zurich, Switzerland.
Okeh, O., Onwosi, Ch., Odibo, F., 2014. Biogas production from rice husks generated from various rice mills in Ebonyi State, Nigeria. Renewable Energy. 62, 204-208.
Orbegoso, L., Prado, A., 2013. Handbook of rice growing technical handling.
Lambayeque, Peru.

Databases

CILCA 2017

VII Conferencia Internacional de
Análisis de Ciclo de Vida en Latinoamérica

12 al 15 de junio de 2017

Medellín - Colombia

HARMONIZAÇÃO DOS FORMATOS DE CONJUNTOS DE DADOS E RECOMENDAÇÕES PARA PUBLICAÇÃO NO BANCO NACIONAL DE INVENTÁRIOS DO CICLO DE VIDA, SICV BRASIL

ARMONIZACIÓN DE LOS MODELOS DE CONJUNTOS DE DATOS Y RECOMENDACIONES PARA PUBLICACION EN EL BANCO NACIONAL DE INVENTARIOS DEL CICLO DE VIDA, SICV BRASIL

Esp. Carla Gama Lustosa, Me. Tiago Emmanuel Nunes Braga, Dr. Thiago Rodrigues Oliveira, Bel. Lucas Gayoso de Moura Ernest Dias

* Instituto Brasileiro de Informação em Ciência e Tecnologia (IBICT), Brasília,
DF. Brasil, 55 61 3217-6286, E-mail: {carlagama, tiagobraga, thiagorodrigues,
lucasdias}@ibict.br

RESUMO:
Esta pesquisa analisa a eficácia na conversão de conjuntos de dados de ACV entre os diferentes formatos existentes atualmente. Em março de 2015 um conjunto de 14 governos e organismos internacionais formalizou a criação da Rede Global de Interoperabilidade de Dados de ACV (GLAD) que possuía, dentre outras atribuições, a prerrogativa de permitir que dados pudessem ser compartilhados entre os diferentes sistemas informacionais que fazem a gestão de dados de ACV no mundo. Embora a GLAD seja um avanço, seus primeiros resultados práticos estão previstos para o segundo semestre de 2017. O SICV Brasil, sistema brasileiro para gestão de dados de ACV, também é um dos signatários da GLAD e sua demanda por conversão de dados de ACV é latente uma vez que a arquitetura do sistema suporta apenas dados no formato ILCD e uma grande parte dos estudos brasileiros de ACV existentes atualmente estão em outros formatos. Ciente da necessidade de suportar a conversão de dados entre os diversos formatos existentes a fim de permitir a adição de novos datasets ao seu repositório iniciou-se uma série de procedimentos de migração de dados oriundos de diversos software de ACV a fim de aferir e mapear a perda de dados no processo de importação dos datasets no SICV Brasil bem como elaborar um guia que permita otimizar o trabalho de conversão entre os formatos existentes de ICVs.

Palavras chave:
SICV Brasil; conversão de datasets; ILCD; EcoSpold; GLAD.

ABSTRACT:
The present article analyzes the efficiency in the conversion of Life Cycle Assessment datasets amongst the serveral distinct existing formats. In March, 2015, a group of fourteen institutions including governments and international organisms, formalized the creation of the Global LCA Data Interoperability Network (GLAD), which ensured, among other atributions, the prerrogative of allowing that these data could be shared between different informational systems that manages LCA data around the world. Although GLAD may be an advance in the sector, its first practical results will occur in the second semester of 2017. The SICV Brasil, brazillian LCA data management system, is also one of GLAD's signatories. Its demand for LCA data convertion is potential, since the system's architecture supports only data in ILCD format and brazillian studies regarding LCA are, for the most part, supported by other formats. Aware of the need to support the conversion of data between the various existing formats in order to allow the addition of new datasets to its repository, a series of data migration procedures have been initiated from various LCA software to measure and map the loss of data in the process of importing the datasets in the SICV Brasil, as well as to prepare a guide that allows to optimize the work of conversion between the existing formats of LCIs.

Keywords:
SICV Brasil; datasets conversion; ILCD; EcoSpold; GLAD.

1| INTRODUÇÃO

O Banco Nacional SICV Brasil, foi arquitetado para promover inovação aos desafios da sustentabilidade no Brasil, disseminando o conhecimento de ACV e permitindo, assim, que seja levada em conta toda a vida útil do produto ao se analisar os impactos ambientais que o mesmo produz. O SICV Brasil, foi estruturado com base no ILCD, plataforma que está baseada nas normas da ISO 14040:2014 e 14044:2014, que provem a estrutura indispensável para avaliações de ciclo de vida, como estruturado no manual ILCD (EC/JRC, 2010). A rede global de acesso aos dados de ACV (GLAD) é uma rede global constituida por bases de dados de ACV independentes e interoperáveis, ligando múltiplas fontes de dados para apoiar a avaliação do ciclo de vida de uma forma que facilite decisões relacionadas com a sustentabilidade (UNEP 2016), da qual o SICV Brasil faz parte. A escolha do tema teve sua origem há alguns anos, quando foi iniciado um estudo sobre a análise do intercâmbio de datasets quando importados ao SICV Brasil nos formatos EcoSpold e ILCD. A par da importância de se verificar a perda de informações que ocorre com formatos de diferentes softwares quando importados para o SICV Brasil, percebeu-se a necessidade de realizar novos estudos dos formatos para verificar se houveram mudanças em relação ao primeiro estudo e propor um guia que auxilie o usuário na importação de inventários que estão em outros formatos. Partindo dessa perspectiva a intenção desta pesquisa é a de reavaliar os formatos de dados de inventários provindos de diversas bases de dados e propor um guia que auxilie o usuário na importação dos dados. Para o estudo foram utilizados os softwares: EcoEditor for EcoInvent versão 3.6; openLCA versão 1.5; SimaPro versão 8.2; GaBi versão 6.3 e o SICV Brasil, e os formatos ILCD, EcoSpold1 e 2 e CSV. As orientações a seguir foram divididas em procedimentos para uma importação correta dos dados, possibilitando a comparação de cenários.

2| METODOLOGIA

O trabalho seguiu a metodologia do primeiro estudo sobre análise do intercâmbio de datasets entre diferentes softwares de ACV e o SICV Brasil (SILVA, et al, 2016), utilizando para tal o checklist da primeira edição. Sendo assim, com base no estágio de desenvolvimento e nos objetivos propostos da pesquisa, foram selecionados datasets de: eletricidade, cimento, algodão, madeira florestal e soja, provindos das bases ELCD, Gabi e SimaPro, nos formatos EcoSpold1 e EcoSpold2, CSV e ILCD. Após a importação foram verificadas as informações que não foram importadas corretamente ou que na importação apresentavam-se diferentes do formato original da primeira análise feita no checklist, identificando procedimentos de tratamento para tais informações.

3| RESULTADOS E DISCUSSÃO

Para melhor auxiliar o usuário do software, são apresentadas recomendações que auxiliam na importação correta dos dados para o Banco Nacional SICV Brasil.

3.1. Recomendações para importação de inventários

3.1.1. Campos que devem ser preenchidos manualmente no software openLCA para a importação no SICV Brasil:

- Datasets nos formatos EcoSpold 01 e CSV ao serem importados devem ser alterados o campo “Time” com as informações de datas de início e fim, de acordo com a informação contida no arquivo original;
- Datasets do EcoSpold 01 devem ser preenchidas as informações vazias sobre a propriedade de fluxo à qual a unidade deve pertencer, e atribuir um fator de conversão se a unidade for nova, momento da exportação para o formato ILCD;
- Campo ‘Método LCI', deve ser preenchido pois os seus valores impactam no valor do campo do SICV Brasil “Deviation from data selection and combination principles / explanations”;
- Campo “Publication” que é referente no SICV Brasil ao campo Unchanged re-publication of: (source data set);
- Campo “Variable/Parameter” é necessário criar os parâmetros em “Global Parameters” e “Dependent parameters” para importação;
- Campo “LCI method approaches”, o openLCA não tem esse campo, para ser importado a informação vai depender do método padrão selecionado em “Allocation” no campo “Default method”;
- Campo “Modelling constants”;
- Campo “Data cut-off and completeness principles”, para a importação correta deve ser preenchido o campo “Data integrity”;
- O campo “Data selection and combination principles”, deve ser preenchida as inofrmações em “Data selection”;
- Campo “Intended applications”.
- Campo “Access and use restrictions”, no caso de não haver nenhuma restrição o termo “None" é exibido no campo do SICV Brasil.
- Para importações no formato ILCD advindas do software SimaPro, o usuário deve ser bastante conciso no preenchimento das informações no campo “General comment”, pois este não possui tais campos. Os seguintes campos devem ser preenchidos no campo supracitado: “LCI method principle”, “LCI method approaches”, “Modelling constants”, “Data cut-off and completeness principles”, “Data selection and combination principles”, “Deviation from data selection and combination principles / explanations”, “Data treatment and extrapolations principles” e “Completeness product model”.

3.2. Comparação do 1º estudo em relação ao resultado do 2º estudo

A conclusão final após refazer os testes dos datasets do 1º experimento e do presente estudo, é que se faz necessário ainda, o preenchimento manual de informações que não são importadas diretamente para o Banco Nacional SICV Brasil, por isso a necessidade de abrir o dataset no software OpenLCA antes de fazer a importação para o SICV Brasil. O software GaBi se mostrou com o maior nível de completeza dos dados ao ser importado para o SICV Brasil, seguido pelo SimaPro, openLCA e EcoEditor. O estudo concluiu que os dados não importados, devido a nomenclaturas de campos seguindo as orientações propostas neste estudo apresentaram um resultado significativo na concretização da importação das informações para o SICV Brasil. A figura 1 demonstra o resultado final das análises em percentual.

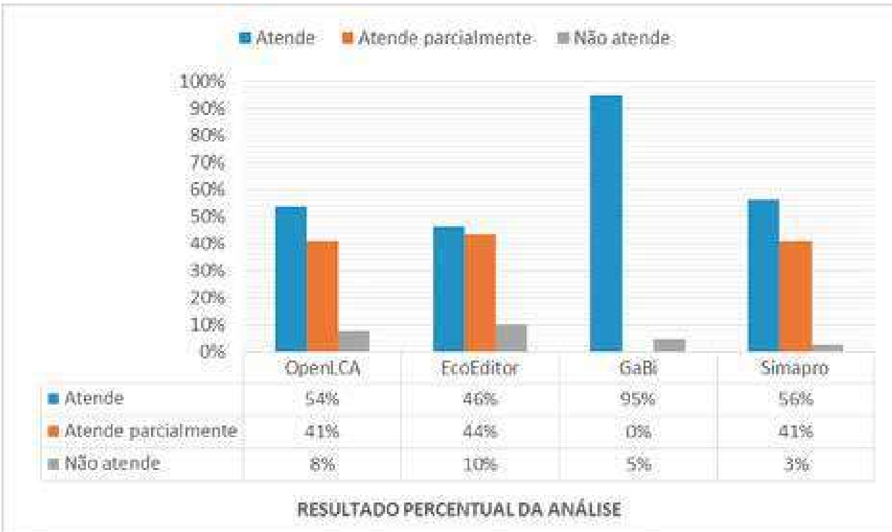


Figura 1 – Resultado global da análise

4| CONCLUSÃO

O estudo concluiu que os inventários de ciclo de vida quando importados ou exportados em diferentes formatos podem caracterizar inconformidades ou falhas que afetam diretamente o grau de infalibilidade das informações nos campos correspondentes. É importante ressaltar que o presente estudo consiste em apresentar ao usuário um guia de procedências nos casos de utilizar os softwares citados no estudo. Percebe-se uma grande similaridade na importação dos dados para o SICV Brasil, quando utilizado o formato ILCD e perdas consideráveis quando usado o formato EcoSpold. A metodologia apresentada não resolve problemas, mas oferece suporte ao usuário para que o processo de importação seja mais efetivo. É necessário perseverar nos estudos sobre nomenclaturas, independentemente do software de origem, para que sejam compatíveis com quaisquer dados a partir de qualquer outro repositório de ACV, perscrutar sobre novas tecnologias, realizando análises que visam um conhecimento mais amplo do problema. As informações no presente artigo podem ser consideradas desatualizadas a partir do lançamento de novas versões dos softwares, devendo os estudos serem constantemente atualizados para se constituírem como análises fidedignas.

Agradecimentos

Ao Prof. Dr. Diogo Aparecido Lopes Silva, Universidade Federal de São Carlos que iniciou em parceria com o IBICT o primeiro estudo sobre os intercâmbios de diferentes tipos de datasets.

Referências

ABNT - Associação Brasileira de Normas Técnicas (2014). NBR ISO 14040: Gestão ambiental, avaliação do ciclo de vida, princípios e estruturas. Rio de Janeiro.

ABNT - Associação Brasileira de Normas Técnicas (2014). NBR ISO 14044: Gestão ambiental, avaliação do ciclo de vida, requisitos e orientações. Rio de Janeiro.

European Commission - Joint Research Centre (JRC) - Institute for Environment and Sustainability, Karlsruhe Institute of Technology (KIT) - Institute for Applied Computer Science (2011): International Reference Life Cycle Data System (ILCD) data format and editor. Disponível em: <http://lct.jrc.ec.europa.eu>.

SILVA, Diogo A. L et al. N. Análise do intercâmbio de datasets entre diferentes softwares de ACV e o banco de dados nacional SICV Brasil: principais limitações e soluções. Congresso Brasileiro em Gestão do Ciclo de Vida, set. 2016.

The Global LCA Data Access Network. Disponível em: <http://drustage.unep.org/resourceefficiency/what-we-do/assessment/life-cycle-thinking/global-lca-data-access-network>. Acesso em: 10/03/2017.

ISO 14001:2015 – What does it mean to take a life cycle perspective

M.A. Martina Prox*

* ifu Hamburg GmbH, Strategy & Collaboration, Max-Brauer-Allee 50, 22765
Hamburg, Germany, + Phone: +494048000911, Fax +494048000922,
E-mail: m.prox@ifu.com

ABSTRACT:

In 2015 the revision of the Environmental Management standard ISO 14001 was published. Companies with a certified Environmental Management System (EMS) will have to follow the new version of the standard latest from 2018. All companies getting a newly certified EMS need to apply the new version directly. The contribution will give insights on the possibilities that companies have to comply with in the requirement of taking a life cycle perspective and which opportunities for Life Cycle Management is bringing this development to the companies.

Companies look for possibilities to address the life cycle perspective from a corporate and organizational perspective. Experiences with Ecological Footprinting, Organizational Environmental Footprinting, Organizational LCA and the application of the Natural Capital protocol are assessed for this contribution.

Keywords:
O-LCA, Natural Capital Accounting, Organizational Environmental Footprint, Ecological Footprint, ISO 14001, ISO / TS 14072

1 | INTRODUCTION

The standard ISO 14001 for Environmental Management Systems has been revised and the new requirement to take a life cycle perspective when assessing the environmental relevance of the company's activities has been added. Environmental Management Systems have been undergoing a development not only reflected in a revised management standard, but also in corporate practice.
Environmental performance assessment according to ISO 14001 used to take into account the system boundaries of one organization. Product environmental performance has been measured considering a life cycle perspective applying LCA according to ISO 14040 and ISO 14044. Both types of approaches have co-existed in corporate practice, but were hardly linked. However, this is changing right now. Organizational and product related approaches require interrelated, quantified physical data with a life cycle perspective.
When first going through an audit using the revised ISO 14001:2015, there is the need to understand and interpret, what it means to take a life cycle perspective. Audit practice and also additional ISO documents emphasize, to consider especially the life cycle stages that are under the control of the organization or that it can influence. In Annex A6.1.2 of ISO 14001:2015, "taking a life cycle perspective" is clarified as follows: "This does not require a detailed life cycle assessment; thinking carefully about the life cycle stages that can be controlled or influenced by the organization is sufficient". The life cycle stages of a product (or service) include acquisition of raw materials, design, production, transportation/delivery, use, end-of life treatment and final disposal. They are explicitly mentioned in 3.3.3 of ISO 14001:2015. In 6.1.2, ISO 14001:2015 requires the organization to consider these life cycle stages when determining the environmental aspects that it can control or influence. With this interpretation it becomes clearer to the extent that all life cycle stages have to be considered, in order to understand where relevant environmental aspects occur, and then determine which of them the organization can control or influence.

ISO 14001:2015 is only one driver of change, also corporate sustainability reporting requires metrics that allow companies to understand, assess and track their overall environmental performance. It has become common to make a claim that a company aims to reduce its "footprint", there are also companies that go a step further and want to become "net positive" or aiming to create only positive environmental impacts with their business activities in order to fully overcome the "become-a-bit-less-bad-paradigm" that causes that the overall human activity is currently beyond planetary boundaries, which is for example shown in the Earth Overshoot Day, that each year is a bit earlier (in 2016: August 8th) and means, that this is the date, where the human society has used all resources and created impacts, that the planet can provide or carry in one year. All the other days of the year the society lives on the substance of the planet.

2| OVERVIEW ON METHODS TO TAKE A CORPORATE LIFE CYCLE PERSPECTIVE

With the aim of taking a life cycle perspective and assessing the overall environmental performance of an organization there are several methods in use and under development. The first methodology used to assess the environmental impact climate change for the whole organization including upstream and downstream activities for many companies is the corporate carbon footprint including scope 3 according to GHG protocol or organizational greenhouse gas accounting according to ISO 14064. Reporting requirements for greenhouse gases trickle down the supply chain in several sectors, which is driven to a certain extent by institutional investors via CDP (former known as Carbon Disclosure Project – now also extending disclosure requests to water and forest). Due to the fact that a Corporate Carbon Footprint (CCF) does not allow to assess the overall environmental impact of an organization, in the context of this contribution its relevance is limited to the possibility for companies to build on their experience with CCF, when using one of the four presented methodologies.

2.1. The Ecological Footprint

The first method using the expression „footprint" is the Ecological Footprint published by Wackernagel and Rees 1990, today hosted by the Global Footprint Network. The relevant document that provides guidance is the 'Ecological Footprint Standards 2009' (Global Footprint Network 2009). Even if mainly used by countries and regions, the method is also applicable to companies. Next to the earlier mentioned document access to a license of the Global Footprint Network equivalent factors is necessary. These factors are used to transform an amount of a certain material used or an amount of waste generated into the unit global hectare. Therefore the result of an ecological footprint is expressed in global hectares. This allows to answer the question how much biosphere is used and impacted by the sum of all activities of an organization. Equivalence factors are updated yearly to reflect changes in technology and the ecosystems capacity to cope for example with wastes and emissions. Some limitations have to be mentioned: Nuclear energy cannot be assessed as it is excluded by definition in this method. Also renewable resources cannot be assessed with an ecological footprint.

The setting of the system boundaries should reflect the goal of the assessment, therefore is sufficiently flexible to be capable to address the needs derived from ISO 14001:2015 or also from the corporate reporting.

There are very few published use cases of Corporate Ecological Footprints available. Some examples can be found in the finance sector, with the aim to consider this assessment for investment decisions. Another corporate example is the French waste management company SITA, which uses the method Ecological Footprint to assess and improve their waste management system. For communication with their clients SITA provides them with a footprint calculator.

2.2. Organizational Life Cycle Assessment

ISO/TS 14072:2014 LCA of Organizations and Guidance on Organizational LCA (O-LCA) by UNEP SETAC Life Cycle Initiative have been developed in parallel in order to support organizations apply LCA, which has originally been restricted to be used for products including services. The 2014 published ISO/S 14072 document has to be used jointly with ISO 14040/14044 as it references the original LCA standard and in general follows the same steps, starting with goal and scope. A full O-LCA aims to assess all potential environmental impacts of all activities of an organization along the life cycles of all products of an organization. With an O-LCA a company can therefore answer the question, which potential environmental impacts are attributed to the selected system boundaries. Therefore the overall environmental performance of a company can be assessed and tracked over time, if the analysis is done repeatedly. When determining the system boundaries for an O-LCA companies with experience in Corporate Carbon Footprinting will find the approaches 'operational control', 'financial control' and 'equity share" suggested very familiar.

Depending on the experiences a company already has, the UNEP O-LCA guidance document refers to different pathways, e.g. starting from product LCA experiences or Corporate Carbon Footprint experiences. As the ISO standard and also the UNEP guidance are rather recent documents there is not yet a broad application of O-LCA. The road testing phase for LCA of Organizations initiated by the UNEP/SETAC Life Cycle Initiative is still going on. Companies like BASF, AZBIL CORPORATION, MAHINYA SANYO SPECIAL STEEL, VOLKSWAGEN shared a variety of first experiences with the approach, differing in completeness and effort taken, depending on the goal and scope and the data of existing assessments they could build on (UNEP 2015).

2.3. Organizational Environmental

As a contribution to Europe's "Roadmap to a Resource Efficient Europe" the Organizational Environmental Footprint (OEF) has been developed by the European Commission (EC) and published first in 2013 (European Commission 2013). The original intention of the EC was to create a tool that allows to compare organizations and there overall environmental performance, similar to the Product Environmental Footprint. Such a comparison should be enabled with an OEF sector rule, which is developed in a consensus process among companies representing 80% of a sector. . In case a sector rule existed the approach is very similar to O-LCA. As the relevance of this approach is currently very limited and space in this paper as well, it is left with mentioning it up to here.

2.4. Natural Capital Accounting

A very recent development is Natural Capital Accounting. Even if the expression natural capital is not that new, the guidance document Natural Capital Protocol has only been published in July 2016 by the Natural Capital Coalition.
The development team of the Natural Capital Protocol consists of companies of various sectors, NGOs, universities, auditing companies and consultants and is led by the World Business Council for Sustainable Development. The method aims to enable companies to reach a monetary evaluation of their environmental impacts and also value and understand their dependencies from renewable and non-renewable natural resources or environmental conditions.
Some companies started to publish the results of a Natural Capital Assessment (NCA) as a so called „Environmental Profit & Loss Statement". This should allow to understand, if all activities of a company create an overall positive or negative effect on the environment and how the company`s performance develops over time (Natural Capital Coalition 2016). Until now 55 pilot companies from a variety of industrial sectors have tested the application of the Natural Capital Protocol. Most of them have used existing studies such as Life Cycle Assessments and extended them with a Natural Capital Assessment by attributing a monetary value to environmental impacts derived from LCA (Natural Capital Coalition 2016a).

3 | RESULTS AND CONCLUSIONS

ISO 14001:2015 is a driver to strengthen the life cycle perspective in companies, all methods explained are still rather new or not broadly applied. O-LCA connects well with the existing experiences and in companies such as CCF and Product LCA. The fact that there are standards available belonging to the ISO 14000 series providing guidance for these approaches in a consistent and interlinked manner, improves applicability. ISO standards to support monetary evaluation and the determination of environmental costs and benefits are under development and can be expected to be published within two to three years. This and the broad interest that Natural Capital Accounting receives from industrial stakeholders allows the assumption that NCAs relevance will increase over the next years. Currently the accessibility to and transparency of monetary values for environmental impacts or benefits is one limiting factor to a broader application of Natural Capital Accounting. Being able to express environmental impact and dependencies in monetary terms is seen as an advantage for the systematic inclusion of environmental aspects in corporate decision-making.

References

European Commission. COMMISSION RECOMMENDATION of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. 2013 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013H0179

European Commission. Guidance for the implementation of the EU Organisational Environmental Footprint (OEF) during the Environmental Footprint (EF) Pilot Phase. 2013

Global Footprint Network. Ecological Footprint Standards 2009. 2009 http://www.footprintnetwork.org/images/uploads/Ecological_Footprint_Standards_2009.pdf

ISO/TS 14072: 2014. Environmental management - Life cycle assessment - Requirements and guidelines for organizational life cycle assessment. 2014.

ISO 14040: 2006. Environmental management - Life cycle assessment - Principles and framework. 2006

ISO 14044: 2006. Environmental management - Life cycle assessment - Requirements and guidelines. 2006

Natural Capital Coalition. Natural Capital Protocol. 2016 http://naturalcapitalcoalition.org/protocol/

Natural Capital Coalition. Business Insights – Pilot Testing the Natural Capital Protocol. 2016 http://naturalcapitalcoalition.org/wp-content/uploads/2016/07/ NCC_Pilot_business-insight_16pp_WEB_PM.pdf

UNEP SETAC Life Cycle Initiative. Guidance on Organizational Life Cycle Assessment. 2015 http://www.lifecycleinitiative.org/wp-content/uploads/2015/04/o-lca_24.4.15-web.pdf

THE IMPORTANCE OF PRIMARY DATA FOR LIFE CYCLE ASSESSMENT OF CONSTRUCTION PRODUCTS IN BRAZIL

A IMPORTÂNCIA DE DADOS PRIMÁRIOS PARA A AVALIAÇÃO DO CICLO DE VIDA DE PRODUTOS DE CONSTRUÇÃO NO BRASIL

LA IMPORTANCIA DE LOS DATOS PRIMARIOS PARA LA EVALUACIÓN DEL CICLO DE VIDA DE LOS PRODUCTOS DE CONSTRUCCIÓN EN BRASIL

MSc. Fernanda Silva*, MSc. Rachel Arduin, Elisabeth Diestelkamp*, PhD. Cláudia Teixeira*, PhD. Luciana Oliveira***

* Institute for Technological Research
Av. Prof. Almeida Prado, 532, Butantã, São Paulo, SP, Brazil.
+55 11 3767 4981. E-mail: fbsilva@ipt.br
** Arts et Métiers ParisTech, I2M, UMR 5295.
F-33400, Talence, France

ABSTRACT:
This work presents a study of six construction products: sand, gravel, clay block, concrete block, ready-mix concrete and mortar. National LCIs were developed using primary data collected at manufacturers located in the State of São Paulo, and upstream and downstream processes were based on the ecoinvent database. Datasets available in ecoinvent deemed representative of these six construction products were chosen for comparison. Four impact indicators were calculated: Global Warming Potential, Water Depletion, Cumulative Energy Demand and Resource Depletion. The differences between the national and the international impact results range from 10% to 255%, with an overall average difference of 69%. GWP was the indicator with the least average difference (53%); while Water Depletion had the highest (101%). Regarding the products, the differences considering all impact indicators range from 42% (gravel) to 109% (clay block). The results indicate the importance of national LCIs based on primary data in order to ensure reliable construction LCA studies in Brazil.

Keywords:
Life Cycle Inventory, primary data, construction.

1| INTRODUCTION

Life cycle assessment (LCA) is considered a suitable tool for evaluating the environmental performance of construction products (CBCS et al. 2014). Usually this application of LCA implies limiting its scope to a cradle-to-gate analysis, because a specific construction product may have multiple options of use. However, even cradle-to-gate LCA studies require a significant amount of data in order to develop the life cycle inventory (LCI) of a product.
In Brazil, the national life cycle inventory database is still under development and secondary data sources are not uniform and consensual (Oliveira et al. 2013). As a result, it is common to use LCA data from other locations. However, these data might not be representative of the system product being modelled, due to differences in product composition, manufacturing technology, energy sources, etc. (Colodel 2008; Soust-Verdaguer et al. 2016).
To overcome this problem, some methods were developed to adapt existing life cycle data to local conditions, with varying degrees of complexity (Colodel 2008; Oliveira et al. 2013). The main approach though is the adaptation of macro parameters, such as energy mix (Oliveira et al. 2013; Saade et al. 2014). However, previous research has shown the importance of collecting primary data, at least for the foreground process (Castro et al. 2015; Silva et al. 2015).
The aim of this work is to discuss the importance of primary data for life cycle assessment of construction products in Brazil, based on a study comprising six construction products commonly used in traditional construction.

2| METHODOLOGY

Primary data of the manufacturing processes of six construction products – sand, gravel, clay block, concrete block, ready-mix concrete and mortar – were collected via questionnaires applied during site visits in manufacturers (one for each product) located in the State of São Paulo, Brazil, between the years of 2014 and 2015. When necessary, allocation by mass was applied. In order to develop the Life Cycle Inventories (LCIs) for these construction products, upstream and downstream processes were modelled using the ecoinvent database (version 3.2) (Wernet et al. 2016), considering a cradle-to-gate system boundary.
To assess the importance of primary data, impact results calculated for the national LCIs (Table 1) were compared to the results obtained from similar LCIs available in the ecoinvent database ("Rest of the World" datasets), as shown in Table 2. The analysis was also supported by the examination of ecoinvent metadata (Kellenberger et al. 2007).

Table 1 – Life cycle Assessment impact categories and methods.

Impact category	LCIA Method
Global Warming Potential (GWP)	IPCC 2013, 100 years' timeframe (IPCC 2013)
Water Depletion (WD)	ReCiPe Midpoint H (Goedkoop et al. 2009)
Cumulative Energy Demand (CED)	Cumulative Energy Demand (Frischknecht et al. 2007)
Abiotic Depletion Potential (ADP), reserve base	ILCD Midpoint (European Commission & Joint Research Centre 2012)

Table 2 – Ecoinvent datasets chosen for comparison with Brazilian datasets.

Product	Corresponding ecoinvent dataset	Reference product
Sand	Gravel and sand quarry operation	Sand
Gravel	Gravel production, crushed	Gravel, crushed
Clay block	Clay brick production	Clay brick
Concrete block	Concrete block production	Concrete block
Ready mix concrete	Unreinforced concrete production, with cement CEM II/A	Concrete, normal
Mortar	Cement mortar production	Cement mortar

The impact results were calculated using Simapro (version 8.2.0.0). The relative difference between the LCIA results obtained from the LCIs developed by IPT based on primary data gathered in Brazil and from the ecoinvent datasets was calculated according to the following equation:
relative difference = (result IPT – result ecoinvent) / result ecoinvent (%)

3| RESULTS AND DISCUSSION

Table 3 presents the relative differences between the impact assessment results calculated for the LCIs developed in this research and for ecoinvent LCIs, by product. It must be highlighted that gravel and sand (aggregates) are used in the manufacturing of concrete block, ready-mix concrete and mortar. Since we opted to use the Brazilian datasets when developing the LCIs of these products, they also contribute to part of the differences observed in their results.

Table 3 – Relative differences between impact assessment results of IPT and ecoinvent datasets.

Product	Impact category				Average absolute difference (by product)
	GWP	WD	CED	ADP	
Sand	+ 50%	- 99%	+ 85%	- 16%	63%
Gravel	- 67%	- 39%	- 50%	- 12%	42%
Clay block	- 90%	+ 255%	- 49%	- 40%	109%
Concrete block	+ 10%	+ 121%	+ 112%	- 44%	72%
Ready-mix concrete	+ 72%	- 64%	+ 58%	+ 55%	62%
Mortar	- 28%	- 29%	- 20%	+ 197%	69%
Average absolute difference (by impact category)	53%	101%	62%	61%	69%

A high correlation was observed between GWP and CED results, and therefore their discussion will be presented together. For sand, diesel and energy consumption determined by IPT were higher than in ecoinvent and that explains the higher GWP and CED result for Brazil. Regarding gravel, diesel and energy consumption determined by IPT were lower and consequently the results for GWP and CED. Besides the differences between the gravel extraction processes – in Brazil quarrying is done by explosion while in Europe it is an open pit excavation – there might be though an underestimation of diesel consumption by the Brazilian manufacturer who delivered primary data.

For the clay block, the main difference regarding GWP and CED is the use of saw dust as fuel for the tunnel kiln in the factory visited in Brazil – the CO2 generated in the combustion is biogenic – whereas in the ecoinvent dataset the main fuels are natural gas, heavy fuel oil and light fuel oil. For the concrete block: although GWP is highly influenced by cement type and content in cementitious products, in this case, the higher GWP (and also CED) of the IPT dataset is explained by the electricity consumption, that contributes with 30% of the final result. The electricity consumption in ecoinvent was extrapolated from cement cast plaster floor production, which is quite lower.

The cement content of the ready-mix concrete assessed by IPT is 363 kg cement/m³ concrete, while that of the ecoinvent dataset is 200 kg/m³ - the dosage considered by IPT is of a concrete for cast-in-place walls that needs formwork to be disassembled in 48 hours. This explains the difference observed in the GWP and CED. Regarding the mortar dataset, IPT found a lower GWP mainly due to the cement content (0,12 kg/kg versus 0,2 kg/kg of ecoinvent) and cement type (IPT considers a cement type with 6-20% alternative constituents while ecoinvent uses “cement, Portland”). On the other hand, IPT considers the use of quicklime in the composition of mortar (0,037 kg/kg), which explains why the GWP result is only 28% lower than in ecoinvent.

For WD indicator, the average difference between IPT and ecoinvent results is 101%. For clay and concrete block, the IPT results are superior due to electricity consumption, once the main source of electrical energy in Brazil is hydroelectric power and the evaporation of water in hydro reservoirs is considered. Brazilian aggregates have a lower WD, explained by differences in the excavation processes, that also entails a lower WD for the ready-mix concrete. The difference between WD results for mortar is related to the silica sand content inventoried by IPT (0,21 kg/kg), which is lower than in the ecoinvent dataset; however, there might be an underestimation of this indicator because drying of artificial sand (crushed gravel) was not considered.

The average difference between IPT and ecoinvent results for ADP is 61%. Sand, clay block and gravel available in Ecoinvent present a higher ADP result due to the energy mix (mainly related to nuclear energy share). For concrete block (and also gravel) the higher results for Ecoinvent processes are due to a higher consumption of rubber and steel for equipment maintenance. Ready-mix concrete assessed by IPT presents a higher ADP due to cement content as previously mentioned. The higher ADP value found by IPT for mortar is associated with kraft paper production used for packing (it accounts for 95% of the final ADP indicator).

4| CONCLUSIONS

Overall relative difference of LCIA results of Brazilian and ecoinvent datasets was high – results range from 10% to 255%, and the average absolute difference is 69%. The main reasons for this finding were differences in process parameters such as energy consumption levels, fuel types and product composition.

The results of this study demonstrate the importance of primary data collection in order to have reliable life cycle assessment of construction products. However, reliability also requires extending data collection, not only because of data representativeness, but also for having reference values of LCI flows and LCIA results to which specific product data can be compared, aiming at a better analysis.

Acknowledgements

To “Fundação de Apoio ao Instituto de Pesquisas Tecnológicas” (Fipt) for the financial support for this research.

References

Castro, A.L. et al., 2015. Análise da viabilidade técnica da adaptação de dados internacionais de inventário de ciclo de vida para o contexto brasileiro: um estudo de caso do concreto para paredes moldadas no local. In.: Anais do 57º Congresso Brasileiro do Concreto. Bonito: IBRACON, pp. 1–16.
CBCS, MMA & PNUMA, 2014. Aspectos da Construção Sustentável no Brasil e Promoção de Políticas Públicas. 132p.
Colodel, C.T.M., 2008. Systematic approach for the transferability of life cycle inventory data between countries. In International Conference on EcoBalance. Tokio, p. 4.
European Commission & Joint Research Centre, 2012. Characterisation factors of the ILCD Recommended Life Cycle Impact Assessment methods: database and supporting information. 31p.
Frischknecht, R. et al., 2007. Implementation of Life Cycle Impact Assessment Methods, Available at: http://www.ecoinvent.org/fileadmin/documents/en/03_LCIA-Implementation.pdf.
Goedkoop, M. et al., 2009. ReCiPe 2008 - Report I: Characterisation.
IPCC, 2013. Report Climate Change 2013: the physical science basic, Nova Iorque.
Kellenberger, D. et al., 2007. Life Cycle Inventories of Building Products, Dübendorf.
Oliveira, L.A. et al., 2013. Adapting existing life cycle inventory of building products for the Brazilian context. In Sustainable Building Conference. Graz, p. 11.
Saade, M.R.M., Silva, M.G. & Gomes, V., 2014. Methodological discussion and piloting of lca-based environmental indicators for product stage assessment of brazilian buildings. Gestão e Tecnologia de Projetos, 9(1), pp.43–62. Available at: http://dx.doi.org/10.11606/gtp.v9i1.89987%5CnMETHODOLOGICAL.
Silva, F.B. et al., 2015. Development of a method for adapting international LCI data for Brazilian building products. In VI International Conference on Life Cycle Assessment in Latin America - Proceedings. Lima: INTE-PUCP, pp. 21–28.
Soust-Verdaguer, B., Llatas, C. & García-martínez, A., 2016. Simplification in life cycle assessment of single-family houses : A review of recent developments. Building and Environment, 103, pp.215–227. Available at: http://dx.doi.org/10.1016/j.buildenv.2016.04.014.
Wernet, G. et al., 2016. The ecoinvent database version 3 (part I): overview and methodology. International Journal of Life Cycle Assessment, 21(9), pp.1218–1230. Available at: http://dx.doi.org/10.1007/s11367-016-1087-8.