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COMMENTARY AND DISCUSSION ARTICLE

Life cycle assessment in Mexico: overview of development and implementation

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Abstract
Purpose Since 1999, there have been advancements in the use of life cycle assessment (LCA) in Mexico. Many of the efforts, such as training, research, and application of life cycle thinking for decision-making, have been carried out across the government, industrial, and academic sectors, but mostly as independent initiatives, without communication or cooperation between the LCA practitioners. This independent approach to LCA has resulted in the perception that LCA advances in Mexico are minimal. However, there have been advancements and notable achievements. This paper presents a review of the history of the application of LCA in Mexico over the past 15 years.
Methods Information was obtained from bibliographic research (i.e., scientific journals, conferences proceedings, thesis, national reports), informal interviews, and the experiences of the authors.
Results and discussion Results show that up till 2010, the research and academic communities were leading LCA efforts with a focus on waste management topics. After 2010, there was a shift to study energy systems, carbon and water footprint analysis, and the construction sector. In the private sector, early LCA interest came from companies that were heavily invested in international markets and susceptible to growing international and national support for environmental regulation, such as CEMEX, the mining sector, the footwear sector, Mexican Petroleum (PEMEX), and Federal Electricity Commission. Moreover the government sector has attracted international recognition for its National Strategy for Sustainable Consumption and Production, which is based on an LCA approach.
Conclusions Accordingly, LCA has thrived and continues to grow in Mexico. However, to improve future LCA studies, policies, and analysis, a national life cycle inventory (LCI) database needs to be developed and maintained, and care will need to be taken to ensure that there is proper guidance and training to safeguard the quality of LCA methods and results,

Keywords Academic sector · Government · LCA Mexico · Private sector · Review

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1 Introduction

Life cycle assessment (LCA) is thriving in Mexico. Since 1999, there have been advancements in its use. Many of the efforts, such as training, research, and application of life cycle thinking for decision-making, have been carried out across the government, industrial, and academic sectors, but mostly as independent initiatives, without communication or cooperation between the LCA practitioners. This independent

approach to LCA has resulted in the perception that LCA advances in Mexico are minimal. However, there have been advancements and notable achievements. This paper presents a review of the history of the application of LCA in Mexico over the past 15 years. Information was obtained from bibliographic research (i.e., scientific journals, conferences proceedings, thesis, and national reports), informal interviews, and the experiences of the authors.

The evolution of LCA in Latin America has been slower than that in developed countries. Life cycle assessment requires expertise, funds, data, and time, which are often lacking in developing countries. In addition, these countries frequently need to prioritize their resources to resolve other problems of national importance, such as poverty, equity, corruption, health, and education (Arena 2000). However, in the past decade, Mexico has turned its attention to environmental concerns and overcoming many of these early barriers to LCA implementation and adoption.

LCA was first utilized in Mexico during the late 1990s and early 2000s in the government sector. National Institute of Ecology (today National Institute of Ecology and Climate Change) conducted waste management and packaging investigations (INE 2002). Since then, it has become a popular tool for industry to evaluate the environmental impacts of products, implement ecodesign strategies, and improve operation and manufacturing efficiency. Academia has also embraced LCA, using the methodologies to conduct research in various fields. Meanwhile, the government sector in recent years has revived interest in life cycle thinking, exemplified by the publication of the National Strategy for Sustainable Production and Consumption (SEMARNAT 2013).

2 LCA developments in academia

Although the government first explored LCA applications in Mexico, the research and academic communities really were the early pioneers of LCA. Many of Mexico's early LCA researchers were exposed to LCA during their academic training in the USA, Europe, and Asia. They collaborated abroad with researchers on cutting-edge LCA research. These experiences developed their LCA skills and knowledge and connected them to a global network of LCA practitioners and researchers, as demonstrated in the works of Lave et al. (1995) and Lave et al. (1998). Fortunately, many of them returned to Mexico with their knowledge and helped to diffuse LCA tools and concepts through their research and training.

The earliest LCA research led by a Mexican was within the automotive industry. This work was still in conjunction with an international team and conducted outside of Mexico (Cobas-Flores et al. 1998).

Around the same time, the Handbook of Life Cycle Engineering (Molina et al. 1999) was published, which presented concepts, models, and technologies used to improve current practice in life cycle engineering in manufacturing companies.

However, it was not till the late 1990s that the first LCA projects were initiated in Mexico on wastewater treatment plants (Güereca et al. 2001) and hydrogen fuel cells (Dante et al. 2002a). For these early exercises, life cycle inventory data was limited so the research was constricted to projects with easily obtainable data. Both of these research efforts were presented at international conferences during the early 2000s (Dante et al. 2002b; Güereca et al. 2002).

Around the same time, the Asia-Pacific Economic Cooperation (APEC) funded projects by its member countries to gather basic life cycle inventory data on the mining and electricity generation sectors. APEC wanted to build LCA capacity around the region so they supported Mexico to complete an assessment of the mining industry (Suppen Reynaga et al. 2006). As a result of Suppen's work with APEC, she was invited to the launch of the Global Life Cycle Initiative in 2002 as the sole Mexican representative in attendance.

During the mid to late 2000s, waste management was an important policy issue in Mexico so that interest carried over into LCA studies. In 2004, Romero-Hernandez (2004) presented a framework to evaluate the environmental impacts caused by wastewater treatment processes compared to the environmental impact generated by the wastewater emissions to help identify the best technologies to use. Güereca published two papers assessing biowaste management strategies (Güereca et al. 2006, 2007). Although these studies did not analyze Mexican cities, they served as a foundation for future research in Mexico. More recently, this research has developed into a project to evaluate wastewater treatment systems in the Latin American and Caribbean region. The goal is to identify the most sustainable technologies considering the social, economic, and environmental aspects of the wastewater systems (Noyola et al. 2013; Hernández-Padilla et al. 2013; Padilla-Rivera et al. 2013, 2014; Paredes et al. 2014).

Several other waste management-centered LCA studies had also been completed during the mid to late 2000s, including the evaluation of the waste management system in Mexico City (Juárez-López 2008), end-of-life options for cell phones (Padilla-Rivera 2010), construction waste (Domínguez and Martínez 2007), alternatives for bottom of the barrel crude oil waste products (Pulido and Fernández 2007), and soft drink packaging systems (Romero Hernández et al. 2009).

During this time period, LCA was still in its infancy in Mexico but was blossoming abroad, as well as in Latin America. In 2005, the Latin American LCA network was formalized (Suppen Reynaga 2005). This network later became the Ibero-American Life Cycle Network (RICV, Red Iberoamericana de Ciclo de Vida). In addition, this was the time the International Standards Organization (ISO) 14000 standard series were being drafted. The Mexican Institute for Normalization and Certification, in 2008, published the

Mexican versions of the ISO 14040 (NMX-SAA-14040-IMNC-2008) and 14044 standards (NMX-SAA-14044-IMNC-2008) (IMNC 2008a, b).

After 2010, there was a shift in the focus of Mexican LCA studies to energy systems. Santoyo-Castelazo et al. (2011, 2014) and Santoyo-Castelazo and Azapagic (2014) studied the current energy system in Mexico while García Carlos et al. (2011), Hernandez-Galvez et al. (2012), Güereca and Juárez-López (2014), and Vargas et al. (2014) evaluated renewable energy options—sugarcane ethanol production, hydrogen storage, pumped-hydro energy storage, and wind turbines, respectively.

As in other countries, many studies in recent years have focused on the assessment of water and carbon footprints. Farrell et al. 2011a and Farrell et al. 2011b published a report on the water footprint from the production of wheat and maize in Mexico, and Güereca et al. (2013) estimated the carbon footprint of a research institute's operations.

Life cycle tools and analysis have also been applied to building design, construction, and operations. A book focused on LCA for the Mexican construction sector was published in 2012 (Suppen 2013), while Cerón-Palma et al. (2013) used LCA tools to evaluate a green sustainable strategy for social neighborhoods in Yucatan, Mexico; Rosas-Urióstegui (2009) analyzed tourism infrastructure in Calakmul, Campeche, Mexico; Güereca (2013) applied LCA to identify the environmental impacts of alternative fuels to produce cement; and Güereca et al. (2014) used LCA to evaluate the environmental impacts of asphalt and cement concrete pavements. Recently, the Engineering Institute at National Autonomous University of Mexico (UNAM, Universidad Nacional Autónoma de México) competed in the Solar Decathlon in Versailles, France. During the construction and design of the house (CASA UNAM), the team applied LCA to identify the most sustainable materials to use, resulting in a 3rd place finish for the sustainability category (Benitez-Escudero 2014).

3 LCA interest in the private sector

Early LCA interest in the private sector came from companies that were heavily invested in international markets and susceptible to growing international and national support for environmental regulation. CEMEX, one of the world's largest cement producers based in Mexico, conducted life cycle evaluations of their manufacturing processes (Güereca 2013; Güereca et al. 2014). The mining sector in Mexico continued to invest in life cycle inventory methodologies and LCAs for various metallurgical processes (Suppen Reynaga et al. 2006). The footwear sector in Mexico also was interested in LCA because they were hearing about it from their counterparts in Spain. The footwear association contracted the Center for LCA and Sustainable Design (CADIS) to provide LCA training and preliminary studies. This early work in the footwear sector eventually leads to a pilot ecolabeling project funded by the European Commission and managed by United Nations Environment Program (UNEP 2007). The program was designed to promote the use of LCA as a means for quantifying life cycle environmental impacts and establishing common sustainability communication principles.

In addition to the footwear sector, other industry associations in Mexico have been proponents of LCA, especially in the chemical and plastic packaging sectors. Since 2009, they have partnered with their manufacturing members to invest in LCA. These associations worked with academics and consultants to use life cycle tools to understand their environmental impact and foster new ecodesigns (Romero Hernández et al. 2005, 2009).

State-owned and state-operated companies, Mexican Petroleum (PEMEX, Petróleos Mexicanos) and Federal Electricity Commission (CFE, Comisión Federal de Electricidad), were also early adopters of LCA because it provided a means to quantify and evaluate the environmental impacts of their business practices. They are often exposed to public scrutiny so needed methods that allow for fair decision-making. Both organizations have continued to employ and increase the use of life cycle tools for decision-making, and PEMEX has published several reports (Morales-Mora et al. 2012, 2013).

Additionally, the agricultural and livestock sectors have begun to enter to the paradigm of sustainability through LCA. Two projects have been developed in order to identify possible environmental improvements for the meat production (Rivera et al. 2014) and bell pepper production (Güereca and López 2012).

4 Government application of LCA

In 2003, the Mexican government joined other Latin American and Caribbean nations in adopting a regional sustainable consumption and production (SCP) strategy. This early effort to develop SCP policies brought life cycle thinking to the forefront. After the regional strategy was adopted, the government began to update legislation to incorporate an environmental approach, specifically in the Federal Law of Acquisitions (DOF 2000) and in the Federal Law of Integral Solid Waste Management (DOF 2003). The two laws did not explicitly reference LCA but did establish some of the first ecolabeling efforts for recycled paper and sustainable forestry certification for furniture, and recognized shared responsibility among government, consumers, manufacturers, and retailers for waste reduction.

Again in 2006, the federal government applied life cycle thinking to the development of the National Housing Law (DOF 2006). This legislation sought to reduce the environmental impacts during the various life cycle stages of

residential buildings. The influence from this law paired with the global sustainable construction trend, inspired many LCA studies in the construction sector in Mexico. With tremendous growth in social housing and construction in general across the country, researchers and the government utilized LCA as a tool to measure the potential environmental impact of this new growth, and manufacturers applied LCA to verify the sustainability of their construction materials. In 2012, the National Housing Commission (CONAVI, Comisión Nacional de Vivienda) and the National Council of Science and Technology (CONACYT, Consejo Nacional de Ciencia y Tecnología) hosted an academic conference to present research findings on sustainable construction, including many LCA studies, in order to develop better housing policies.

The energy sector has been a very popular LCA topic for the government. LCA studies have been conducted for in-country electricity generation and fuel production and to analyze future energy production scenarios (Santoyo-Castelazo et al. 2011). LCA tools were utilized to successfully develop balanced biofuel policies since the production of the fuels can have significant environmental impacts. The nonprofit organization Mario Molina Center (CMM, Centro Mario Molina) was funded by PEMEX and the CONACYT to provide analysis of various biofuel feedstocks and manufacturing processes, while INECC developed several biofuel scenarios.

In 2013, Mexico published its National Strategy for Sustainable Consumption and Production (NSSCP) (SEMARNAT 2013) and joined an elite group of countries that are applying life cycle thinking to address sustainable consumption and production (UNEP/SETAC 2012). The NSSCP states that a life cycle approach is fundamental to evaluate the environmental, social, and economic impacts of a product for decision-making purposes. It also (1) calls on the government to develop regulations based on life cycle management (LCM), (2) notes that the private sector should incorporate LCM into their production and material acquisition processes, and (3) recommends more training for the public on the life cycle impacts of products (SEMARNAT 2013). In addition, Mexico has been an active member of the UNEP's Marrakesh Process, hosting national roundtables on sustainable consumption and production to increase awareness and identify national priorities (UNEP 2011).

In 2014, the Mexican government embarked on a new ecolabeling program in support of the NSSCP. SEMARNAT, in partnership with Carbon Trust,[1] is piloting the program with the tequila, glass bottle, and cement industries. These industries have been early adopters of LCA so will work with the government to develop the carbon footprint assessment method and label. The program is in early stages of development but has the potential to drive further development of LCA in Mexico.

[1] http://www.carbontrust.com

5 Catalysts of LCA development

There are two catalysts that have spurred the development of LCA in Mexico. The first was the creation of Mexican versions of the ISO 14040:2006 and ISO 14044:2006 LCA standards—Environmental Management—Life Cycle Analysis—Principles and Framework (NMX-SAA-14040-IMNC-2008) and Environmental Management—Life Cycle Analysis—Requirements and Guidelines (NMX-SAA-14044-IMNC-2008) (IMNC 2008a, b). These provided a local reference to the standards in Spanish, which helped with diffusion of the LCA framework and guidance. A second catalyst was the 4th International Life Cycle Assessment Conference in Latin America (CILCA-2011) hosted in Coatzacoalcos, Mexico. The Coatzacoalcos conference, sponsored and hosted by PEMEX, CADIS, and the Engineering Institute of UNAM (IIUNAM), attracted a diverse group of LCA researchers and practitioners from Mexico. This conference was one of the first opportunities for many of these professionals to connect with the growing number of Mexico LCA practitioners. From this meeting, the idea of a Mexican LCA network blossomed, and a few months later, the Mexican Life Cycle Network (REMACV, Mexicana de Análisis de Ciclo de Vida) was formed (Güereca and Suppen 2012). The network has helped to bring together participants from diverse disciplines and institutions and promotes the continued development of LCA training and application. More recently, other related networks have formed, including the Mexican Industrial Ecology Network and the Climate Change and Life Cycle Division of the Inter-American Sanitary and Environmental Engineering Association (AIDIS, Asociación Interamericana de Ingeniería Sanitaria y Ambiental). Again, these networks are helping connect LCA tools and concepts to new audiences.

6 International influences on the development of LCA

Early on, Mexican LCA experts participated in international efforts, including the development of the ISO 14000 series of standards, programs and reports of the UNEP/SETAC Life Cycle Initiative, and development of RICV. However, Mexico has also benefitted greatly from the assistance of international programs and organizations to further LCA efforts in country. Funding from the UNEP/SETAC Life Cycle Initiative has helped to build LCA capacity. They support the CILCA conferences in Latin America, including the conference in Coatzacoalcos. Additionally, they co-funded the International Seminar on LCA Databases in Latin America and the first life cycle assessment seminar both hosted in Mexico in 2013. UNEP funded many of the sustainable consumption and production efforts, which have increased the use of life cycle thinking, while the European Commission provided the finances to develop the first ecolabeling project for the footwear

industry. The German government assisted the development of the National Strategy for Sustainable Consumption and Production with funding and technical assistance, and the British government is aiding with the recent ecolabeling pilot program. The assistance and seed funding from these countries has been critical to the initiation of many life cycle-based programs, policies, and research.

7 Future development of LCA in Mexico

LCA is here to stay in Mexico. It is has been broadly adopted but still faces some challenges in reaching the levels of use and application as in Europe.

Developing expertise and knowledge in LCA concepts and tools is very important to the use and diffusion of LCA in Mexico. The first LCA courses in Mexico date back to the late 1990s. Since then, there has been a steady increase in the number of courses and a diversification in the programs that offer them. In addition to LCA training at the university level, many professionals are exposed to LCA concepts during workshops and forums. Although LCA training has increased significantly since the 1990s, the network of active LCA practitioners in Mexico is still relatively small.

To understand the current network of LCA practitioners in Mexico, a questionnaire was shared with the 30 participants of the International Seminar on LCA Databases in Latin America in 2013. To supplement the responses to the questionnaire, interviews were conducted with another 21 LCA practitioners who did not participate in the expert meetings. The 51 practitioners contacted were distributed across industry 18 %, universities 43 %, research centers 27 %, government 8 %, and consultancy firms 4 %.

According to the survey, the number of LCA practitioners has increased in the last 5 years. This is in agreement with a global trend identified in Bjørn et al. (2013) and Souza and Barbastefano (2011), which found higher LCA activity between 2007 and 2012 during the time period of the implementation of the 2nd phase of UNEP/SETAC Life Cycle Initiative that centered on the dissemination and application of LCA. However, for the future success of life cycle thinking and the application of LCA tools, the number of practitioners will need to continue to grow.

Another important aspect to increase the use of LCA in Mexico is the development of life cycle inventory datasets to represent local materials and processes. Many LCA projects have referenced European life cycle inventories, such as ecoinvent,[2] when local data is not available. This practice can lead to inaccurate results so the development of local datasets is important for company, public, and government decision-making. CADIS is currently developing the Mexican Life Cycle Inventory Database (MEXICANIUH). They are bringing together existing life cycle inventory data from the development of legislation, such as the National Housing Law and ecolabeling efforts for textiles, cardboard, plastics, and leather industries, and from previous LCA projects by CFE and PEMEX on electricity generation, fuels, and petrochemicals. The first version of the database is scheduled for release next year but will require a lot of effort to keep updated and to expand it.

[2] http://www.ecoinvent.ch/

8 Conclusions

The use of LCA in Mexico has increased over the years. In the early stages of implementation in the country, government and academia mainly used the methodology with a strong focus in evaluating solid waste management systems and alternatives. Since then, different organizations have adopted the life cycle approach for decision-making.

The industrial sector has shown a growing interest in the development of studies and communication of LCA results, and institutions in important sectors such as electricity, construction, and wastewater treatment are carrying out new research to improve their transparency and decision-making. Meanwhile, the government sector and policy makers have reinforced the importance of the methodology in laws and regulations, such as the National Strategy for Sustainable Consumption and Production.

For LCA to continue to grow in use in Mexico, a national life cycle inventory (LCI) database needs to be developed and maintained. The effort will need to be a collaborative partnership of government, industry, academic, and consultants. An integration of efforts between these sectors will also help identify where to invest resources for life cycle inventory data generation and systematic reviews. And work groups need to be developed and strengthened to help create regional methodologies that report local environmental impacts—an important step in generating a national LCI database. Additionally, as the number of LCA projects and practitioners increases, care will need to be taken to ensure that there is proper guidance and training to safeguard the quality of LCA methods and results.

References

Arena AP (2000) Spreading life-cycle assessment to developing countries. J Ind Ecol 4:3–6

Benitez-Escudero V (2014) Casa UNAM en el Decatlón Solar de Versalles. Proyecto multidisciplinario en el que participó el IIUNAM. Gaceta del Instituto de Ingeniería 104: 14–15. ISSN: 1870-347X

Bjørn A, Owsianiak M, Laurent A, Molin C, Bochsen Westh T, Hauschild M (2013) Mapping and characterization of LCA networks. Int J Life Cycle Assess 18(4):812–827

Cerón-Palma I, Sanyé-Mengual E, Oliver-Solà J (2013) Towards a green sustainable strategy for social neighbourhoods in Latin America: case from social housing in Merida, Yucatan, Mexico. Habitat Int 38:47–56

Cobas-Flores E, Bustani A, Mackay PW, Ramirez B et al (1998) An analysis of the vehicle end-of-life in the United States. SAE Technical Paper 982213:1998. doi:10.4271/982213

Dante RC, Güereca LP, Caballero CA, Neri L (2002) Environmental impact assessment of a wastewater treatment plants through life cycle analysis. Eurosustain 2002. Rhodas Grece

Dante RC, Güereca LP, Neri L, Escamilla J, Aquino L, Celis J (2002b) Life cycle analysis of hydrogen fuel: a methodology for a strategic approach of decision making. Int J Hydrogen Energy 27:131–133

de Souza CG, Barbastefano RG (2011) Knowledge diffusion and collaboration networks on lifecycle assessment. Int J Life Cycle Assess 16: 561–568

DOF (2000) Ley de Adquisiciones, Arrendamientos, y Servicios del Sector Público. Diario Oficial de la Federación. Cámara de Diputados del H. Congreso de la Unión. 04/01/2000

DOF (2003) Ley General para la Prevención y Gestión Integral de los Residuos. Diario Oficial de la Federación, Cámara de Diputados del H. Congreso de la Unión. 08/10/2003

DOF (2006) Ley de Vivienda. Diario Oficial de la Federación, Cámara de Diputados del H. Congreso de la Unión. 27/06/2006

Domínguez JA, Martínez E (2007) Reinserción de los residuos de construcción y demolición al ciclo de vida de la construcción de viviendas. Ing Rev Académica la FI-UADY 3:43–54

Farrell C, Turpin S, Suppen N (2011a) Assessment of the water footprint of wheat in Mexico. LCM-2011 Conference. Towards Life Cycle Sustainability Management, ISBN 978-94-007-1898-2, pp 161–170

Farrell C, Turpin S, Suppen N (2011a) Assessment of the water footprint of maize in Mexico. IV Conferencia Internacional de Análisis de Ciclo de Vida (CILCA2011) Hacia Rio*20. Coatzacoalcos, Veracruz, Abril 2011

García Carlos A, Fuentes A, Hennecke A, Riegelhaupt E, Manzini F, Masera O (2011) Life-cycle greenhouse gas emissions and energy balances of sugarcane ethanol production in Mexico. Appl Energy 88:2088–1097

Güereca LP (2013) Evaluación comparativa de los impactos ambientales de la producción de clínker con combustible fósil frente a combustible derivado de los residuos municipales. Gaceta del Instituto de Ingeniería 86. ISSN: 1870-347X

Güereca LP, Juárez-López CR (2014) Environmental performance comparison between pumped-hydro energy storage and battery energy storage system in Mexico. SETAC Europe 24th annual meeting. 11–15 May 2014, Basel Switzerland

Güereca LP, López OI (2012) Life cycle assessment of the production of bell pepper in greenhouses in Mexico. Primer Congreso Internacional de la División de Cambio Climático de AIDIS (AIDIS DC3). October 28–30. Viña del Mar, Chile

Güereca LP, Suppen N (2012) Life cycle assessment in Mexico: overview and development of the Mexican LCA network. SETAC Case Study Symposium. December 6–11. Copenhagen Denmark

Güereca LP, Dante RC, Neri L, Caballero CA (2001) Analysis of feasibility of a wastewater treatment plant through the LCA and development of software. 11th Annual Meeting, SETAC Europe

Güereca LP, Dante RC, Caballero CA, Neri L (2002) Environmental impact assessment of a wastewater treatment plant in a university through life cycle analysis. Euro-Sustain 2002

Güereca LP, Gassó S, Baldasano JM, Jiménez-Guerrero P (2006) Life cycle assessment of two biowaste management systems for Barcelona, Spain. Resour Conserv Recycl 49:32–48

Güereca LP, Agell N, Gassó S, Baldasano JM (2007) Fuzzy approach to life cycle impact assessment. Int J Life Cycle Assess 12: 488–496

Güereca LP, Torres N, Noyola A (2013) Carbon footprint as a basis for a cleaner research institute in Mexico. J Clean Prod 47:396–403

Güereca LP, Juárez-López C, Ossa A (2014) Evaluación comparativa de los impactos ambientales de dos tipos de pavimentos. Gaceta del Instituto de Ingeniería 104: 18–20. ISSN: 1870-347X

Hernandez-Galvez G, Probst O, Lastres O (2012) Optimization of autonomous hybrid systems with hydrogen storage: life cycle assessment. Int J Energy Res 36:749–763

Hernández-Padilla F, Güereca LP, Noyola A (2013) Environmental evaluation of different wastewater treatment systems: activated sludge, UASB and stabilization ponds in Latin American and the Caribbean region. The 6th International Conference on Life Cycle Management. Gothenburg 2013

IMNC (2008a) Norma Mexicana IMNC. ISO 14040. 2006. Gestión Ambiental . Análisis del ciclo de vida- Principios y marco de referencia

IMNC (2008b) Norma Mexicana IMNC. ISO 14044. 2006. Gestión Ambiental . Análisis del ciclo de vida- Requisitos y directrices

INE (2002) Análisis de los mercados de diversos materiales vírgenes y reciclados para la producción de envases. Instituto Nacional de ecología. Dirección General de Onvestigación en Pollítica y Economía Ambiental. SEMARNAT. México

Juárez-López CR (2008) Análisis de ciclo de vida del sistema de gestión de residuos sólidos de la Ciudad de México. Master Degree Thesis. Directed by Leonor Patricia Güereca PhD. Tecnológico de Monterrey. Campus Estado de Mexico. Mexico

Lave LB, Cobas-Flores E, Hendrickson CT et al (1995) Using input-output analysis to estimate economy-wide discharges. Environ Sci Technol 29:420A–426A

Lave LB, Joshi S, MacLean HL, Horvath A, Cobas-Flores E (1998) Environmental Input–output Life Cycle Analysis: A Summary of Results Including a Comparison with the SETAC Approach. Total Life Cycle Conf Expo

Molina A, Sánchez J, Kusiak A (1999) Handbook of Life Cycle Engineering: Concepts, Models and Technologies. Springer

Morales-Mora MA, Rosa-Dominguez E, Suppen Reynaga N, Martinez-Delgadillo SA (2012) Environmental and eco-costs life cycle assessment of an acrylonitrile process by capacity enlargement in Mexico. Process Saf Environ Prot 90:27–37

Morales-Mora MA, Dominguez ER, Ibarra AA, Suppen N, Martínez Delgadillo S (2013) A methodological improvement for assessing petrochemical projects through life cycle assessment and eco-costs. Int J Life Cycle Assess 19:517–531

Noyola A, Morgan-Sagastume JM, Güereca LP (2013) Selección de tecnologías para el tratamiento de aguas residuales municipales: Guía de apoyo para ciudades pequeñas y medianas. Instituto de Ingeniería de la Universidad Nacional Autónoma de México y IDRC Canadá. ISBN: 978-607-02-4822-1

Padilla-Rivera A (2010) Análisis de ciclo de vida del plan de manejo de celulares al final de su vida útil en la Ciudad de México. Master Degree Thesis. Directed by Leonor Patricia Güereca PhD. Tecnológico de Monterrey. Campus Estado de Mexico. Mexico

Padilla-Rivera A, Güereca LP, Morgan-Sagastume JM, Noyola A (2013) Propuesta Metodológica para Evaluar Impactos Sociales con un Enfoque de Ciclo de Vida. CILCA 2013. Mendoza Argentina, Abril 2013

Padilla-Rivera A, Morgan-Sagastume JM, Noyola A, Güereca LP (2014) Life cycle assessment of wastewater treatment facilities. Case study: Iztapalapa, Naucalpan, Los Angeles and Phoenix. XXXIV Congreso AIDIS. Monterrey México. November 3–6, 2014

Paredes MG, Güereca LP, Noyola A (2014) Methane emissions by management and treatment of municipal wastewater in Mexico: with

emphasis on activated sludge with anaerobic digestion. IWA Conference. Water, Energy and Climate Conference 2014. México D.F.

Pulido R, Fernández G (2007) Mexican bottom of barrel life cycle environmental improvement proposal. Energy 32:619–626

Romero Hernández O, Detta E, Palacios A et al. (2005) Product life cycle management applied into soft drink containers in Mexico, a multi product case study. LCM 2005 2nd Int Conf Life Cycle Manag

Romero Hernández O, Romero Hernández S, Muñoz D et al (2009) Environmental implications and market analysis of soft drink packaging systems in Mexico. A waste management approach. Int J Life Cycle Assess 14:107–113

Romero-Hernandez O (2004) Applying life cycle tools and process engineering to determine the most adequate treatment process conditions. A tool in environmental policy. Int J Life Cycle Assess 10: 355–363

Rosas-Urióstegui I (2009) Infraestructura hotelera sostenible: como parte escencial para el desarrollo de turismo sostenible en el municipio de Calakmul Campeche. Master Degree Thesis. Directed by Leonor Patricia Güereca PhD. Tecnológico de Monterrey. Campus Estado de Mexico. Mexico

Santoyo-Castelazo E, Azapagic A (2014) Sustainability assessment of energy systems: integrating environmental, economic and social aspects. J Clean Prod 80:119–138

Santoyo-Castelazo E, Gujba H, Azapagic A (2011) Life cycle assessment of electricity generation in Mexico. Energy 36:1488–1499

Santoyo-Castelazo E, Stamford L, Azapagic A (2014) Environmental implications of decarbonising electricity supply in large economies: the case of Mexico. Energ Conserv Manage 85:272–291

SEMARNAT (2013) Estrategia nacional de producción y consumo sustentable. Secretaría de Medio Ambiente y Recursos Naturales. Gobierno de la República. México

Suppen N (ed) (2013) Análisis de ciclo de vida y ecodiseño para la construcción en México. Hábitat Sustentable. Unievrsidad Autónoma de San Luis Potosí and CADIS

Suppen Reynaga N (2005) LCA Association in Latin America. Int J Life Cycle Assess 10:376–376

Suppen Reynaga N, Carranza M, Huerta M, Hernández MA (2006) Environmental management and life cycle approaches in the Mexican mining industry. J Clean Prod 14:1101–1115

UNEP (2007) Ecolabeling project. Enabling Developing Countries to Seize Ecolabelling Opportunities. Ecolabelling Mexican footwear. http://ecolabelling.unep.fr/ (November 12, 2014)

UNEP (2011) Paving the way for sustainable consumption and production: The Marrakech Process progress report. UNEP 104

UNEP/SETAC (2012) Greening the Economy Through Life Cycle Thinking Ten Years of the UNEP / SETAC Life Cycle Initiative, pp 1–64

Vargas AV, Zenón E, Oswald U, Islas JM, Güereca LP, Manzini FL (2014) Life cycle assessment: a case study of two wind turbines used in Mexico. Applied Thermal Engineering (2014), http://dx.doi.org/10.1016/j.applthermaleng.2014.10.056