Zeszyty Naukowe
Quality. Production. Improvement

No. 2(3)
2015
pp. 24-36

Dorota Klimecka-Tatar[1], *Manuela Ingaldi* [2]

LCA - LIFE CYCLE ASSESSMENT AS A STEP IN A IMPROVEMENT OF THE INDUSTRY-ENVIRONMENT RELATIONS

Abstract: The chapter presents a brief description of the specifics of the 14040 (14044) standard implementation according to production process. There were discussed the objectives and analysis techniques of Life Cycle Assessment based on a number indicators determined based on Life Cycle Inventory. There were also presented simplified matrixes which allow you to create a complete quantitative documentation relating to the environmental impact of production.

Key words: Life Cycle Assessment, environment, ISO standard, waste management

1. Life Cycle Assessment - definition

Life Cycle Assessment (LCA) is one of a number of environmental management techniques to study aspects of the maid environment and the potential environmental impacts over the lifetime of the product, starting from raw material acquisition through production, use, until the liquidation (ARVESEN A., BRIGHT R. M., HERTWICH E. G. 2011, KRUSZEWSKA I. 1995).

In ISO 14040 LCA is defined as the "*compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle*". The LCA is a tool for the analysis of the environmental burden of products at all stages in their life cycle, from the beginning, such as extraction of resources, through the production of materials, product equipment and the final product, and the use of the

[1] dr inż., Czestochowa University of Technology, Faculty of Management, Institute of Production Engineering, e-mail: klimt@wip.pcz.pl
[2] dr inż., Czestochowa University of Technology, Faculty of Management, Institute of Production Engineering, e-mail: manuela@gazeta.pl

product to the management after it is in perspective discarded, either by reuse, recycling or final disposal The total system of unit processes involved in the life cycle of a product is called the "product system" and the model is presented on Fig. 1. (HAUSCHILD MICHAEL Z., ET ALL. 2013, 8.ISO 14040:2009, ISO 14044:2009)

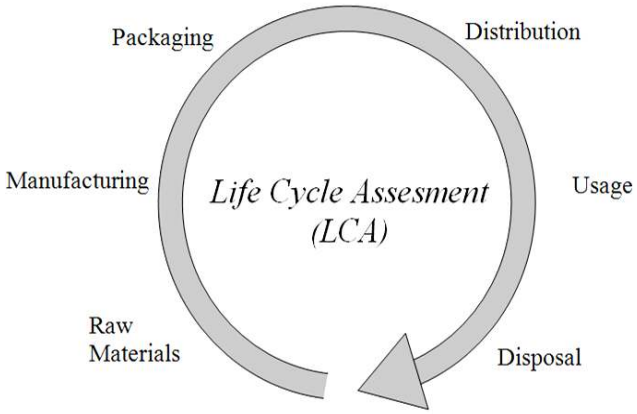

Fig.1. Life Cycle Assessment model

Source: ISO 14040:2009, ISO 14044:2009

Analysis based on environmental life cycle of the product, has become one of the most important methods of assessing the effects of products on the environment. This complex method of analysis we try to gain insight into the entire product life cycle, which includes:

- extraction and technological processing of raw materials,
- the acquisition of energy resources,
- production of semi-finished products and subassemblies,
- production and distribution of energy,
- pacacking, transportation and distribution,
- alternatives handling of the product after use.

Such an approach is particularly important when there are alternative routes and choices of those variations are less harmful to the environment. Analysis, modeling and planning for the LCA is also a very important factor from the point of view of production cycle economic solve. Well identified impact on the environment during LCA also allows reduce costs. (MOREAU V, WEIDEMA B. P. 2015, PLEVIN RICHARD J., DELUCCHI MARK A., CREUTZIG FELIX 2014).

2. Life Cycle Assessment of product

The method of LCA (Life Cycle Assessment) tries to assess (evaluate) all impacts on the environment, which in its life cycle provokes a product with the aim that this product is environmentally optimized. It represents a compilation and evaluation of all inflows (inputs), effluent (outputs) and the potential environmental impact of certain production system throughout its life cycle.

The results of the analysis of Life Cycle Assessment represent the information base for decision-making in the context of wider environmental policy of the company. They can help in determining how different technological processes differ in terms of environmental impacts, which are the most influential stages in the life cycle and where environmental impacts are most problematic and where the life cycle occur. Furthermore, the findings of the LCA figure out how to change the effects on the environment, if a company decides to change the packaging materials and how they change impacts on the environment, if we change the transport route for goods or packaging materials from a new supplier (Fig.2).

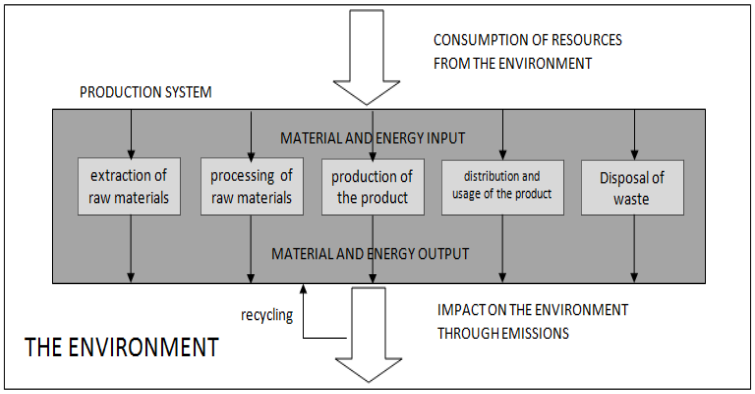

Fig.2. Life Cycle of product

Source: based on RYSZKO A. 2003

The LCA method is currently the only internationally standardized method for assessing the impacts of products throughout their life cycles. It has become the leading method of ascertaining the impact of products on the environment in the world. With it we find both, advantages and risks, for the optimization of products from raw material extraction to waste management (FORBES R. MCDOUGALL, WHITE P.R., FRANKE M., HINDLE P. 2008., RYSZKO A. 2003).

3. Principles of LCA research

No matter of the Life Cycle Assessment study range, it is carried out in four phases outlined in the Standard: Environmental Management - Life Cycle Assessment - Requirements and guidelines of ISO 14044 (Fig.3).

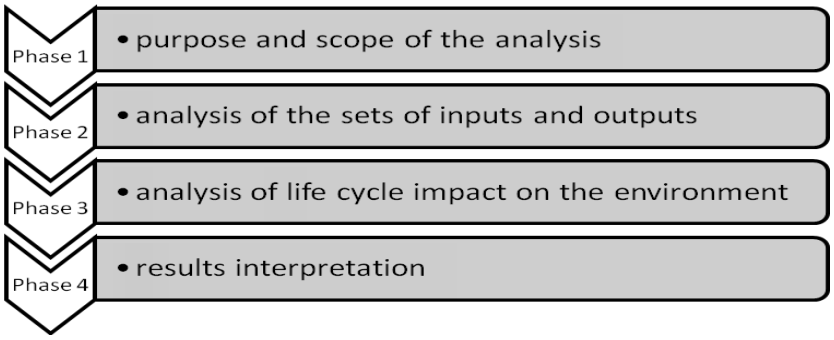

Fig.3. Steps in Life Cycle Assessment research

Source: based on RYSZKO A. 2003

Analysis of Life Cycle Assessment regardless of the firm's activities and irrespective of the type of research facility (product, product) runs with in four phases, followed by the succession.

Phase 1 - determination the purpose and scope of the analysis,

Phase 2 - (Life Cycle Inventory) - analysis of the sets of inputs and outputs (analysis of the technological process, material and energy required for the process and emissions and waste, as well as the identification of potential sources of their formation, take into account issues of intangible assets, such as noise and odor.

Phase 3 - life cycle impact assessment on the environment (transformation of the data collected in the impact category indicators or categories of damage),

Phase 4 - results interpretation (application and verification of results).

4. Parameters in LCA research

The use of Life Cycle Assessment requires knowledge of various parameters of possible numerical presentation (Fig.4).

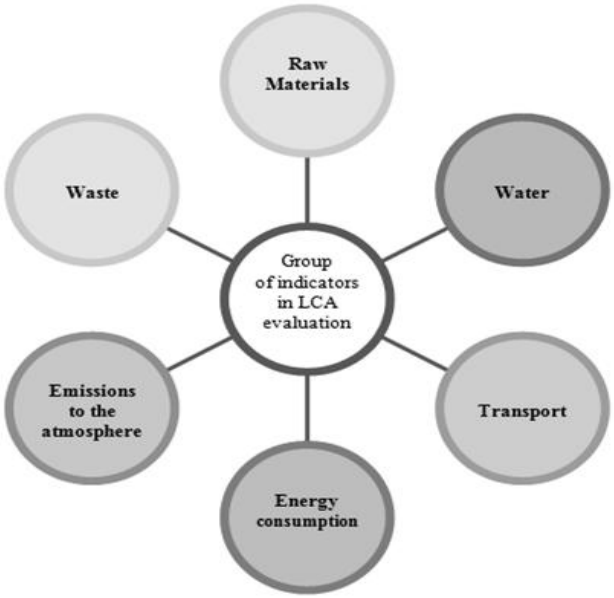

Fig.4. Main groups of indicators in Life Cycle Assessment evaluation

Source: based on SANGWON SUH, GJALT HUPPES 2005.

Essential parameters that are required to determine in Life Cycle Assessment represent six area:

- Raw materials: specify the amount of raw materials used in kg.
- Water: water consumption should be attributed to the finished product produced.
- Transport: it should take into account the capacity transport and the length of the road, which overcomes.
- Energy consumption: consider the energy consumption in all phases of the production process.
- Emissions to the atmosphere: specify the atmospheric emissions in all phases of the production process, and specify the emissions generated during transport.
- Waste: The different types of waste attributed to the relevant phases of the production process.

The environmental parameters are determined by three groups of parameters:

1. **Resources consumption**
   - consumption of non-renewable resources,
   - consumption of renewable resources,
   - consumption of primary energy sources,
   - consumption of electricity,
   - consumption of water.
2. **Pollutant emissions expressed by the potential impact on the environment**
   - global warming,
   - acidification,
   - destruction of the ozone layer,
   - the formation of photochemical oxidants,
   - eutrophication.
3. **The generated waste**
   - hazardous waste,
   - waste for recycling,
   - other waste,
   - depending on the type of materials used it has to be definied information about the emissions of the different substances (Table 1).

Life cycle assessment of the product considering all phases of the life cycle from extraction of raw materials to the disposal of waste generated in the phase (all data refer to the functional unit). Data must be obtained directly from the individual production stations and cells in the organization.

In the absence of data specific to the manufacturing process can use data from existing databases - this applies particularly to the production of energy, materials, semi-finished products transportation (BRANDÃO MIGUEL, LEVASSEUR ANNIE ET ALL. 2013, CHUM H., A. FAAIJ, ET AL. 2011).

Table 1. The groups of environmental parameters

ENVIRONMENTAL PARAMETERS		
Resources consumption	**Pollutant emissions expressed by the potential impact on the environment**	**The generated waste**
– consumption of non-renewable resources [kg, MJ], – consumption of renewable resources [kg, MJ], – consumption of primary energy sources [MJ], – consumption of electricity [kWh], – consumption of water [m^3].	– global warming [kg eq CO_2], – acidification [kmol eq H^+], – destruction of the ozone layer [kg eq CFC^{-11}], – the formation of photochemical oxidants [kg eq C_2H_4], – eutrophication [kg O_2].	– hazardous waste [kg], – waste for recycling [kg], – other waste [kg], – depending on the type of materials used it has to be definied information about the emissions of the following substances: SO_2, NO_x, Cd, Cr, Hg, Ni, Pb, Zn

Source: based on SANGWON SUH, GJALT HUPPES 2005.

5. Evaluation of parameters in LCA research

When evaluating the product life cycle may be helpful tables (table model presented below Table 2-4). Parameters in table should be strictly addressed to type of production in the enterprise.

In Table 2 should be listed all materials used to construct the product. To further evaluation the impact on the environment it is necessary to cardinality determination (with respect to one piece or a series of production, to tonnage or other adequate metric units). Due to such comparison

it is possible to complete determination the percentages structure of the components included in the product.

Table 2. List of materials and chemical substances (example- product about 1,50 kg, created from 3 different materials)

Material	Mass, kg	Content, %
Material 1	0,63	42
Material 2	0,48	32
Material 3	0,39	26

Source: own study - example

Table 3. Matrix of product

Chase of life	Environmental aspect					
	Material	Energy usage	Solid waste	Liquid waste	Pollution	Sum
Prior to manufacturing	M1	E1	SW1	LW1	P1	
Production	M2	E2	SW2	LW2	P2	
Packaging and distribution	M3	E3	SW3	LW3	P3	
Usage	M4	E4	SW4	LW4	P4	
End of life	M5	E5	SW5	LW5	P5	
Sum	$\sum_{i=1}^{5} Mi$	$\sum_{i=1}^{5} Ei$	$\sum_{i=1}^{5} SWi$	$\sum_{i=1}^{5} LWi$	$\sum_{i=1}^{5} Pi$	

Source: own study - example

Table 3 refers to the effect on the environment of all the stages of the product - as a combined result, or it can be broken down into individual components. The complexity of this matrix depends only on the element design. In the case of a product consisting of many subassemblies, it is possible to prepare for each component as an intermediate product and

then as a final. Table 4 already requires knowledge of the values determined on the basis of the previously discussed factors.

Table 4. Resorces usage and their effect

Parameter	Pre-production phase	Production	Usage	End of life	Sum
global warming (kg eq CO_2)					
photochemical smog (kg eq C_2H_4)					
eutrophication (kg O_2)					
acidification (kmol eq H^+)					
Destruction of ozone layer					
hazardous waste (kg)					
Rother waste (kg)					
Waste to recycling (kg)					

Source: own study - example

Very important, on the basis of LCI results to determine of midpoint categories and their impact on the environment. Especially indicate the damage that are caused by evaluated parameters (Fig.5) (HUIJBREGTS M, et all. 2001, MARK A. J. ET ALL. 2001, REBITZER G., ET ALL. 2004).

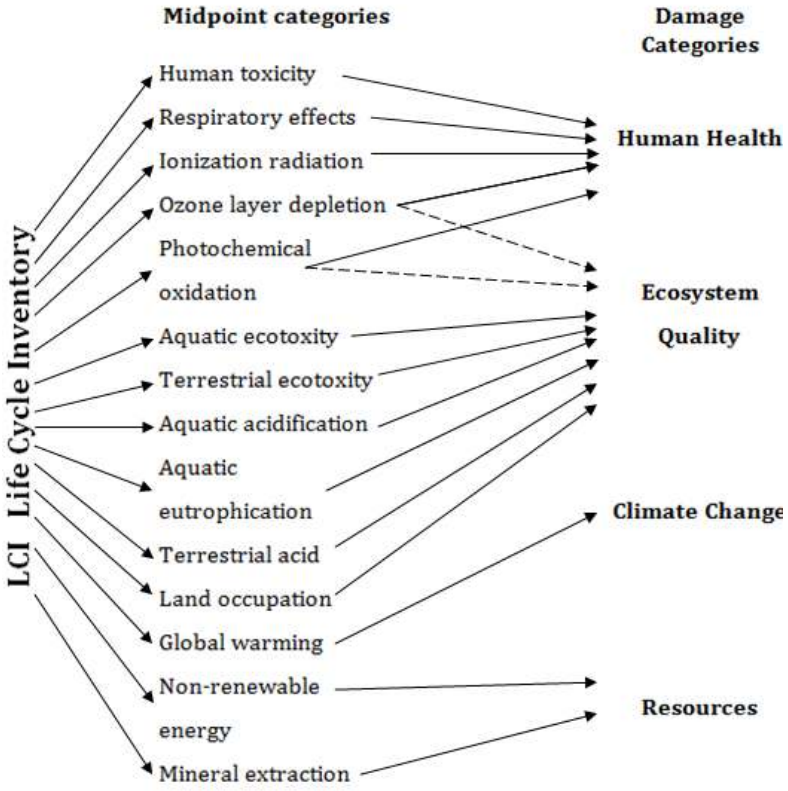

Fig.5. Midpoint categories and damage categories in Life Cycle Inventory (LCI)

Source: HUIJBREGTS M, ET ALL. 2001, MARK A. J. ET ALL. 2001, REBITZER G., ET ALL. 2004

Summary

Caring for the environment it is recommended for all enterprises (any sector) explore the potential of control the impact of production on the ecosystem. With the Life Cycle Assessment techniques and standardized tasks of 14040 and 14044 standards it is possible to create conditions for the production of minimized impact on the environment. Both thorough

analysis of Life Cycle Assessment and the setting indicators in Life Cycle Inventory help to reduce consumption of raw materials, decreasing the losses caused by excessive production of waste, and thus contribute to the promotion of eco-world politics.

Bibligraphy

1. ARVESEN A., BRIGHT R. M., HERTWICH E. G. 2011. *Considering only first-order effects? How simplifications lead to unrealistic technology optimism in climate change mitigation.* Energy Policy. Volume 39. Issue 11. Pp. 7448–7454.
2. BRANDÃO MIGUEL, LEVASSEUR ANNIE, KIRSCHBAUM MIKO U. F., WEIDEMA BO P., COWIE ANNETTE L., JØRGENSEN SUSANNE VEDEL, HAUSCHILD MICHAEL Z., PENNINGTON DAVID W., CHOMKHAMSRI KIRANA. 2013. *Key issues and options in accounting for carbon sequestration and temporary storage in life cycle assessment and carbon footprinting*. The International Journal of Life Cycle Assessment. Volume 18, Issue 1, pp 230-240.
3. CHUM H., A. FAAIJ, MOREIRA J., BERNDES G., DHAMIJA P., DONG H., GABRIELLE B., et al. 2011. Bioenergy. In *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, edited by O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, et al. Cambridge, UK, and New York: Cambridge University Press.
4. FORBES R. MCDOUGALL, WHITE P.R., FRANKE M., HINDLE P. 2008. *Integrated Solid Waste Management: A Life Cycle Inventory.* Blackwell Science
5. HAUSCHILD MICHAEL Z., GOEDKOOP MARK, GUINÉE JEROEN, HEIJUNGS REINOUT, HUIJBREGTS MARK, JOLLIET OLIVIER, MARGNI MANUELE, AN DE SCHRYVER, HUMBERT SEBASTIEN et all. 2013. *Identifying best existing practice for characterization modeling in life cycle impact assessment*. The International Journal of Life Cycle Assessment. Volume 18, Issue 3, pp 683-697
6. HUIJBREGTS M, NORRIS G A, BRETZ R, CIROTH A, MAURICE B, VON BAHR B, WEIDEMA B P, DE BEAUFORT A S H. 2001. *Framework for modeling data*

uncertainty in life cycle inventories. International Journal of Life Cycle Assessment Volume 6. Issue 3. pp. 127‑132.

7. ISO 14040:2009 *Environmental Management – Life Cycle Assessment – Principles and Framework*.
8. ISO 14044:2009 *Environmental Management – Life Cycle Assessment – Requirements and Guidelines*.
9. KRUSZEWSKA I. 1995. *Strategies to Promote Clean Production*. Beverley Thorpe Greenpeace International, Oct, translation Andrzej Wojtasik
10. MARK A. J. HUIJBREGTS, GREGORY NORRIS, ROLF BRETZ, ANDREAS CIROTH, BENOIT MAURICE, BO VON BAHR, BO WEIDEMA, ANGELINE S. H. DE BEAUFORT. 2001. *Framework for modelling data uncertainty in life cycle inventories.* The International Journal of Life Cycle Assessment, Volume 6, Issue 3, pp 127-132.
11. MOREAU V, WEIDEMA B. P. 2015. The computational structure of environmental life cycle costing. International Journal of Life Cycle Assessment Volume 20 Issue 10. pp. 1359‑1363.
12. PLEVIN RICHARD J., DELUCCHI MARK A., CREUTZIG FELIX. 2014. *Using Attributional Life Cycle Assessment to Estimate Climate-Change Mitigation Benefits Misleads Policy Makers.* Journal of Industrial Ecology. Volume 18, Issue 1, pp.73–83.
13. REBITZER G., EKVALL T., FRISCHKNECHT R., HUNKELER DNORRIS G., RYDBERG T., SCHMIDT W.-P., SUH S., WEIDEMA B.P., PENNINGTON D.W. 2004. *Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis, and applications*. Environment International. Volume 30, Issue 5, pp. 701–720.
14. RYSZKO A. 2003. *Ocena cyklu życia jako narzędzie wspomagające rozwój produktu* W: Organizacja i Zarządzanie Zeszyt Piętnasty, Zeszyty Naukowe Politechniki Śląskiej, Wydawnictwo Politechniki Śląskiej, Gliwice.
15. SANGWON SUH, GJALT HUPPES 2005. *Methods for Life Cycle Inventory of a product*. Journal of Cleaner Production. Volume 13. Issue 7. pp. 687-697.