ECOLOGICAL FOOTPRINT ASSESSMENT OF HIGHER EDUCATION APPLYING LIFE CYCLE ASSESSMENT FRAMEWORK. CASE STUDY: UNIVERSITAT POLITÈCNCIA DE VALÈNCIA

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Universities from all over the world has recently developed Ecological Footprint to assess their environmental impact. The methodologies applied are variations of the original methodology designed for territories. The analysis of these studies highlight the lack of standardization of the methodology and the lack of comparability with in results.
Seeking for a standardized methodology that provides comparable results, an Ecological Footprint Assessment (EFA) methodology based on Life Cycle Assessment (LCA) is proposed. The assessment is applied to case study Universitat Politècnica de València (UPV).
Results brings out the high impact of the emission component of the EFA – Carbon Footprint – that represents the 85% of EFA. Weaknesses of the methodology are also discussed and the usefulness of a verified Environmental Management System is proven.

Keywords: Ecological Footprint Assessment; Life Cycle Assessment; Higher Education Institutiosn; univeristy

EVALUACIÓN DE LA HUELLA ECOLÓGICA DE UNIVERSIDADES APLICANDO LAS BASES DEL ACV. CASO DE ESTUDIO: UNIVERISTAT POLITÈCNICA DE VALÈNCIA

Universidades de todo el mundo han llevado a cabo, en los últimos años, estudios de Huella Ecológica para evaluar su impacto ambiental. Las metodologías utilizadas son variaciones de la metodología original diseñada para territorios. Destaca entre estos estudios, la falta de estandarización y de comparabilidad.
Con el fin de buscar la estandarización y comparabilidad, se propone una metodología para el cálculo de la Huella Ecológica de la Universidad aplicando las bases del Análisis de Ciclo de Vida (ACV). La metodología propuesta se aplica al caso de estudio de la Universitat Politècnica de València (UPV).
De los resultados de Huella Ecológica para la UPV destaca el elevado impacto de su componente en emisiones - la Huella de Carbono – que representa el 85% de la Huella Ecológica. Se discuten las debilidades de la metodología y la utilidad de contar con un Sistema de Gestión Ambiental verificado queda comprobada.

Palabras clave: Huella Ecológica; Análisis de Ciclo de Vida; instituciones universitarias; universidad

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Agradecimientos: The authors would like to thank the Universitat Politècnica de València and especially the Environmental Office for its help in gathering and making available the environmental information needed to perform this study.

1. Introduction

The Ecological Footprint Assessment (EFA) is an environmental indicator defined as 'the ecologically productive territory needed to produce the resources used and to assimilate the waste and emissions produced by a population with a specific life mode indefinitely' by M. Wackernagel and W.Rees (1996). Over last years, it has been applied to different land areas as countries, regions, etc. (Lo Iacono-Ferreira, et al., 2011a). Moreover, EFA methodology has been adapted to assess companies and different types of organizations; higher education institutions (HEI) are not an exception (Lozano et al., 2015).

EFA provides a result in global hectares (gha). A gha represents the average productivity of all biologically productive areas (measured in hectares) on earth in a given year (Wackernagel & Rees, 1996). It is a manageable measure to report as the community target can visualize the dimension of a hectare easily.

The responsibility of HEI to be a benchmark of good practices made analysts, researchers and stakeholders search for tools to assess and report the results of their efforts to reduce the environmental impact of their activities. Several HEI adapted EFA methodology to their organization and published their results (Lo Iacono-Ferreira, In press).

However, not standardize methodology, add uncertainty to the assessment. Studies have been made in order to detect weaknesses and strengths of EFA by its comparison with a well known and standard assessment tool, the Life Cycle Assessment (LCA) (Lo Iacono-Ferreira, et al, 2011b).

LCA (International Organization for Standardization, 2006a) is a tool developed to evaluate impacts associated to a product or services. Four objectives can be distinguished in LCA application:

- Identify opportunities to improve productive cycle of the product.
- Detect as much information as possible to assist in decision making.
- Select pertinent environmental indicators and it measure technics.
- Produce marketing.

LCA goal is to analyzed potential environmental impacts and environmental aspects along the entire life cycle of the product or service. A material and energy flow analysis has to be made (International Organization for Standardization, 2006b).

Universitat Politècnica de València is a HEI located in Valencia region, Spain. It has an Environmental Management System (EMS) that has been verified in EMAS (Torregrosa-López, et al., 2016). Both staff and researchers are engage with the system in order to better manage the environmental impact of the institution.

This work is based on first author master's final project where EFA of universities has been analyzed. Further, main characteristics of LCA has also been studied in relationship with those EFA methodologies applied to universities. As a result, the following methodology is proposed and assessed for case study of UPV with data of 2014.

3. Case study

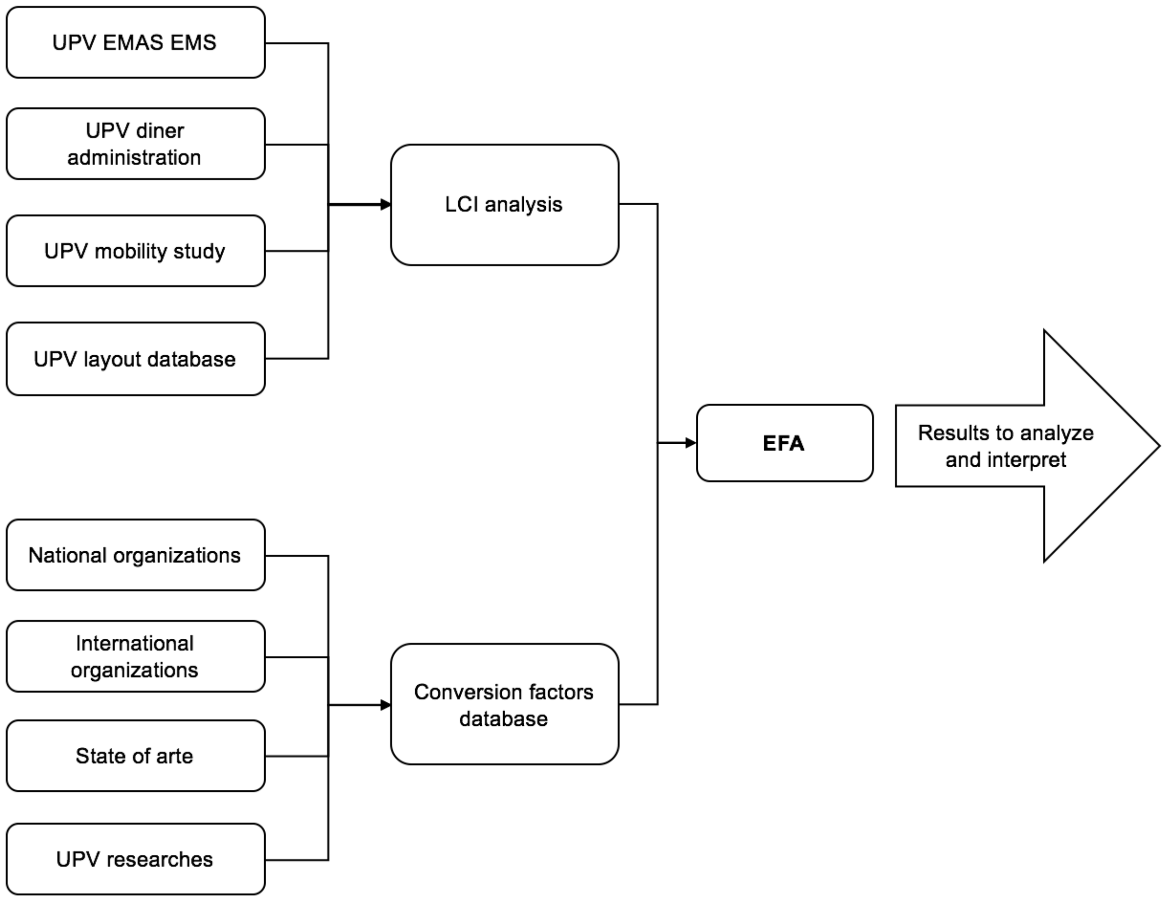
UPV was founded in 1971, although some of it' s schools date back to nineteenth century. It is located in Valencian region and has three main campuses: Alcoy, Gandía y Vera with more than 38000 students, over 8000 staff members and 51 ha.

To assess EFA of UPV, LCA framework is used through the following steps according to LCA standard (International Organization for Standardization, 2006b):

- Definition of goals, scope, functional unit, system boundaries and data requirement
- Life Cycle Inventory analysis (LCI)
- Life Cycle Impact Assessment (LCIA)
- Interpretations of results (in section 4)

Figure 1 shows the assessment scheme where data sources are identified.

Figure 1: Assessment scheme



3.1 Definition product system, functional unit, system boundaries and data requirement

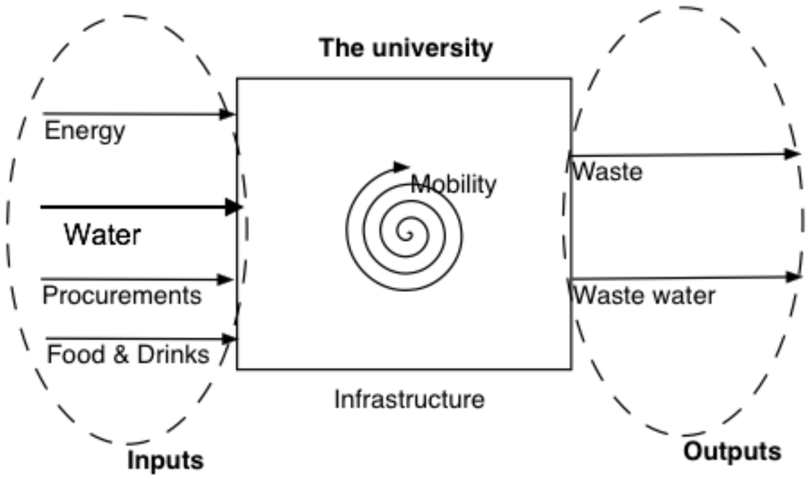
The product system has been defined as The University, including all three campuses and it community. The functional unit chosen is students. System boundaries has been defined on geographical basis.

About data requirement, when ever is possible, direct measures are preferred. Estimations are used if no direct measures are available but estimation methodology must be clearly reported. Regarding conversion factors, only reliable sources are used and consistent geolocation is pursued.

3.2 Life Cycle Inventory analysis (LCI)

The LCI is defined considering the university as a whole, including all its activities. In this point, attention need to be paid as mobility from / to the university is a linked activity. Although the activity does not take place entirely inside geographical limits, it is considered as an interesting aspect that deserves to be assessed. Figure 2 shows the flow analysis for UPV.

Figure 2: LCI analysis



Aspects under consideration for UPV EFA are energy and water consumption, procurements, food & drinks consumption, waste and wastewater generation, infrastructure and mobility.

3.3 Life Cycle Assessment Inventory (LCAI)

In this section, three characteristics of aspects are developed: how data is gathered, where does conversion factors come from and how the impact of the aspect is assessed.

Energy consumption gathers five types of energy: electricity, gasoil, natural gas, gasoline and propane. Data over these aspects is obtained from invoices details and considered as direct measures. Same procedure is applied to water consumption and transferred to wastewater treatment as all incoming water needs to be treated as output somehow. Water consumption includes well and main water.

UPV has no centralized purchasing system. Each department manage their own budget as schools and general services. For this aspect, the only item available to assess is paper (virgin and recycled) used in the copy service. Direct data was obtained from Alcoy's copy service. Data for Valencia and Gandía Campus was inferred by a simple rule of three. A similar process was applied with food & drinks consumption as the manager of Alcoy coffee shop and diner provided the amount of menus sold during the year.

Waste aspect includes paper & paperboard, electrical waste, light packaging, debris, manure, glass, municipal solid wastes (MSW) and batteries. EMS weight electrical waste, debris, manure, batteries and the glass of Valencia and Gandía campuses. The glass of Alcoy is estimated by the same EMS as well as MSW, light packaging and paper & paperboard. The method applied to estimate the amount of glass in Alcoy and MSW is similar; a reference value that describe the rate generation of waste for each city (RG) is multiplied by the number of people associated to each campus (P) and the number of working days (D) as shown in equation 1.

$$\text{Data} = RG \cdot P \cdot D \qquad (1)$$

When no RG is available, a different estimation method is used. The waste collecting system is structured in sectors within cities. The collecting company weight the material collected by sectors (W). Light packaging and paper & paperboard estimation is based on the relationship between the numbers of containers installed at the university (UC) and the total number of containers (TC) of the sector. This ratio gives the proportion of weight attribute to the university as shown in equation 2.

$$\text{Data} = W \cdot UC / TC \qquad (2)$$

EMS carried out a mobility study for 2014 where emissions associated to the mobility of all UPV community are calculated. The detail procedure can be seen in (Environmental office, 2015).

UPV layout database served as source for infrastructural data to include the constructed area for each year. The impact of constructed area is considered in equal proportions along its useful time life set at 50 years.

The data of each aspect considered is convert to impact units (gha) by a simple equation (3) where d_i represents the data of each aspect, CF the conversion factor and EF the Ecological Footprint.

$$EF = \sum_{i=1}^{n} d_i[units] \cdot CF \left[\frac{gha}{units}\right] \qquad (3)$$

The world average forest factor, the ratio that assess the land needed, in gha, to absorb certain amount of CO_2e, in kg, used is 4400 $kgCO_2e$ / gha (Escuela Politécnica Universitaria de Valladolid, 2009). Table 1 gather all conversion factors used to convert data into global hectares.

Table 1. Conversion factors and sources

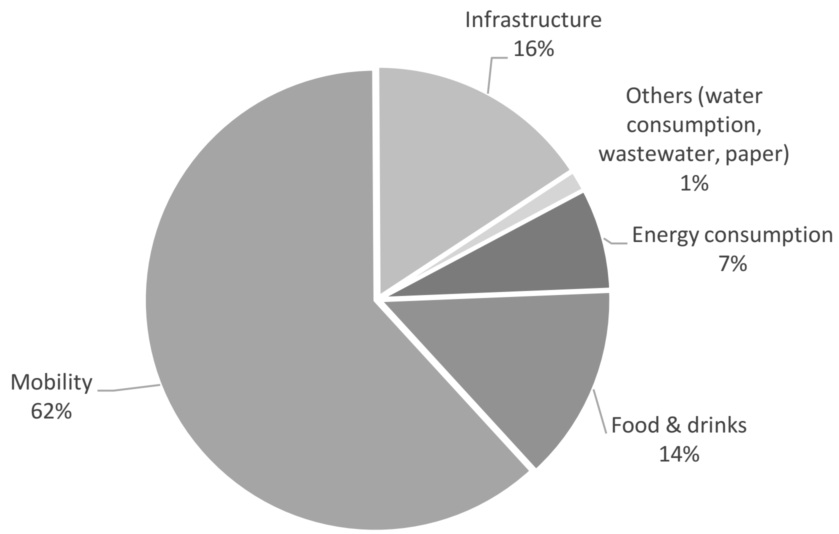
Aspect	Unit	GHG emission factor $kgCO_2e$/unit	Land factor gha/unit	Source / author
Energy				
Electricity	kWh	0.237		WWF (2015)
Gasoil	L	2.786		MAGRAMA (2015)
Natural gas	kWh	0.201		MAGRAMA (2015)
Gasoline	L	2.196		MAGRAMA (2015)
Propane	kg	2.938		MAGRAMA (2015)
Water				
Well water	m^3	0.5	2.5E-05	Marañón et al. (2008)
Main water	m^3	1.62		Lemos (2013)
Procurements				
Virgin paper	Kg	1.84		(EPUV, 2009)
Recycled paper	Kg	0.61		(EPUV, 2009)
Food & Drinks	[menu]	0.00233	0.00235	Barret (2002)
Infrastructure	m^2	520	1	Cuchí & López Caballero (1999)
Waste				
Paper & paperboard	kg	1.91E-02	2.63E-07	Marañón et al. (2008)
Electrical waste	kg	5.59E-02	3.51E-06	Marañón et al. (2008)
Light packaging	kg	1.62E-01	1.37E-06	Marañón et al. (2008)
Debris	kg	2.79E-03	2.56E-07	Marañón et al. (2008)
Manure	/kg	1.06E-02	5.65E-07	Marañón et al. (2008)
Glass	kg	0	4.49E-08	Marañón et al. (2008)
MSW	kg	6.42E-03	4.88E-06	Marañón et al. (2008)
Batteries	kg	2.36E-01	6.84E-07	Marañón et al. (2008)

Note: All conversion factors are geo-located in Spain except for the food & drinks factor that was build with data from UK. EPUV stands for *Escuela Politécnica Universitaria de Valladolid* (see reference).

3. Results and discussion

EFA of UPV for 2014 is 7690 gha. The composition of EFA is presented in de following figure.

Figure 3. EFA UPV results for 2014



Four aspects stand out of the figure: Energy with a 7%, infrastructure with a 16%, mobility with 62% and food & drinks with 14%. Other aspects are grouped in an insignificant category.

Paper, a concept associated with education, it happens to have an insignificant impact. However, by not being able to assess purchases fully, some relevant impacts are being excluded: computers, lab equipment, electronics, chemical substances, office furniture, etc. All items that might have a significant impact. As infrastructure, long life devices would need a special consideration to allocate their impact along all its useful life. Water consumption and wastewater treatment are not relevant aspect of the environmental impact of this HEI.

The minimization consumption of energy is one of the main goals of the environmental office. Several actions have been taken to make a more efficient use of fuel and electricity. All energy sub-aspects are fully included in the EMS giving results relevance and transparency.

Food and drinks is an aspect based on estimations from real data of a small part of the community (Alcoy campus). It is the believe of the authors that the assessment of food can be improved by it direct inclusion in the regular monitoring of the EMS.

Mobility has been the subject of EMS in 2014 where the most recent mobility diagnosis took place. Regular information is gather during each course with the objective on knowing and understanding the way UPV community moves. As a public and recognized institution, UPV might have certain influence to negotiate changes on public transport to encourage it used minimizing the impact of mobility. This will impact not only on EFA results for UPV but on the area where its placed.

Results by functional unit are shown in table 2.

Table 2. Ecological footprint by aspects and by functional unit (students) in gha

Aspect	EF [gha by student]	UPV EF [gha]
Energy		
Electricity	2.16	5.88E-05
Gasoil	32.34	8.79E-04
Natural gas	498.50	1.36E-02
Gasoline	4.23	1.15E-04
Propane	11.60	3.15E-04
Water		
Well water	23.46	6.38E-04
Main water	67.69	1.84E-03
Procurements		
Virgin paper	7.95	2.16E-04
Recycled paper	3.26	8.86E-05
Food & Drinks	1,064.28	2.89E-02
Infrastructure	1,219.81	3.31E-02
Mobility	4,745.77	1.29E-01
Waste		
Paper & paperboard	0.92	2.51E-05
Electrical waste	0.37	1.01E-05
Light packaging	5.36	1.46E-04
Debris	0.44	1.19E-05
Manure	1.01	2.74E-05
Glass	0.01	2.99E-07
MSW	2.14	5.81E-05
Batteries	0.01	2.23E-07

The Carbon Footprint can be assessed directly from the EFA by extracting the category of GHG emissions. For 2014, is 28.9 Tn CO_2e and represents the 85% of EFA results.

4. Conclusions

LCA methodology help to developed a clear EFA. Except for 1, all conversion factors have the same geographical root than the object of study, UPV. However, the origin of these factors it is not always clear. Moreover, improvements need to be accomplish in order to have more accurate data of some aspects like procurement and food consumption.

The Ecological Footprint of UPV shows that the main impact is due to the mobility of the community. However, the lack of a full assessment of the procurement aspect has to be taken under consideration. UPV is already focusing efforts in the reduction of this impact as can be seen in the mobility plan recently published. Furthermore, alternatives to gather procurement information to improve the assessment are being considered.

Results presented by functional unit, students, could constitute a useful tool to inform and engage higher education institution community in direction of a better environmental performance. Further research may shed light on the best way to use this information and how to measure the influence towards a behavioral change to achieve necessary environmental impact reductions.

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