04-019

THE USE OF CARBON FOOTPRINT AS A KEY PERFORMANCE INDICATOR IN HIGHER EDUCATION INSTITUTIONS

Lo-Iacono-Ferreira, Vanesa G.[(1)]; Torregrosa-López, Juan Ignacio[(1)]; Capuz-Rizo, Salvador F.[(1)]

[(1)]Universitat Politècnica de València

The environmental key performance indicators are gaining interest as a tool to internalize environmental performance in the scorecard of decision-making boards of higher education institutions.

The carbon footprint is the indicator commonly used to assess environmental impact related to climate change. Higher education institutions, as any other complex organization, have a wide range of activities and operations that may be contributing to this issue. The carbon footprint is a pressures indicator that can be set as key performance indicator, if it is properly assessed and interpreted.

This paper analyzes the use of carbon footprint as a key performance indicator in higher education institutions and proposes a mechanism to include it in the daily management and decision-making.

Keywords: *carbon footprint; key performance indicator; higher education institutions; decision-making*

EL USO DE LA HUELLA DE CARBONO COMO INDICADOR CLAVE DE DESEMPEÑO EN INSTITUCIONES DE EDUCACIÓN SUPERIOR

Los órganos de gestión de las instituciones de educación superior utilizan cada día más los indicadores clave de desempeño de carácter ambiental, como herramientas para integrar el desempeño ambiental dentro de su cuadro de mandos.

La huella de carbono es un indicador de uso habitual para estudiar el impacto ambiental relacionado con el cambio climático. Las instituciones de educación superior, como cualquier organización compleja, tienen un amplio abanico de actividades y operaciones que pueden contribuir a este problema. La huella de carbono es un indicador de presión que puede utilizarse como indicador clave de desempeño si se evalúa e interpreta adecuadamente.

Este trabajo analiza el uso de la huella de carbono como indicador clave de desempeño en instituciones de educación superior y propone un mecanismo para incluirlo en la gestión y los procesos de tomas de decisiones diarios.

Palabras clave: *huella de carbono; indicador clave de desempeño; universidad; institución de educación superior; toma de decisiones*

Correspondencia: Vanesa Lo Iacono Ferreira. valoia@upv.es

1. Introduction

Key performance indicators (KPIs) are management tools widely applied in decision making process of companies and organizations. KPIs evaluate the degree of development of crucial factors of an organization; usually on economic basis (Kerzner, 2011; Zaman, 2014). When introducing environmental performance indicators to the decision-making process, KPIs might be the most adequate instrument (Lo-Iacono-Ferreira et al., 2018).

Carbon Footprint (CF) is a widely applied environmental indicator that measures the amount of greenhouse gases (GHG) emitted, directly and indirectly by the object of study. CF can be assessed for a product, an organization or a person, in whole or part of its life cycle (International Organization for Standardization, 2013a).

The are several European initiatives related to the reduction of carbon emissions. Higher Education Institutions (HEIs) are leading technical, non-technical and management interventions in this field (Altan, 2010). The influence of HEIs and the magnitude of the changes they can reach is not minor. World HEIs community is over 200 million people (United Nations Educational Scientific and Cultural Organization, 2014) including future top executives and decision makers with the ability to perform significant changes in the climate change policy. This study focus in Higher Education Institutions (HEI).

1.1 Definition of carbon footprint (CF)

CF is considered a simple indicator, easier to calculate than an Life Cycle Assessment (LCA) (when assessing impact of products) or an Organizational Life Cycle Assessment (OLCA) (when assessing impact of organizations). Although it only evaluates a fraction of the environmental performance, the understandability of this indicator has make it gain popularity (Weidema et al., 2008).

Under the DPSIR framework (Smeets and Weterings, 1999) CF is a pressure indicator as it shows the stress that human activities and natural conditions place on the environment. The European Environmental Agency (2014) classifies GHG emissions as type B as it answers the question ‘Does it matter?

There are different standards to assess CF. For organizations, main standards are ISO14064 and GHG Protocol. Pelletier et al, (2014) developed a deep analysis of these standards that offers a helpful overview when choosing the most adequate standard for a particular case.

However, there are significant issues regarding the application of standards that are common as:

- the criteria to choose an accounting method,
- the uncertainty of the emission factors or
- the lack of scientific parameters to define system boundaries.

The definition of boundaries and the specification of quality data requirements are key factors on a CF assessment (Tao Gao et al., 2013).

For a good definition of CF, standards propose the definition by scopes:

- Scope 1 gathers direct emissions
- Scope 2 accounts indirect emissions associated to energy consumption
- Scope 3 congregates all other indirect emissions

Other crucial aspect of the assessment is de quality of conversion factors and data. Information regarding scope 1 and 2 are easy to obtain using the accounting system as a source (Lo-Iacono-Ferreira et al., 2017a). Yet, emissions of scope 3 might significantly depend on third hand information as suppliers, employees, students or third parties. This is the reason why scope 3 is not assessed or, in the best scenario, it is just estimated. Robust Environmental Management Systems (EMS), as those verified in EMAS, are useful tools to assess this indicator even in scope 3 (Torregrosa-López et al., 2016).

1.2 Characteristics of Key Performance Indicators (KPIs)

Performance indicators focus on goals and serves as reference points for it evaluation (Barnetson and Cutright, 2000). In particular, environmental PIs provide data and information about the organization's environmental performance (International Organization for Standardization, 2013b).

The usability and consistency of a performance indicator depends on certain characteristics (Bonaccosi et al., 2007; Bauler, 2012; International Organization for Standardization, 2013b):

- Intelligible: Meaning and theoretical terms should be clear and well-defined.
- Useful: Indicators must be easy to measure and easy to apply.
- Standardized: A standardization or functional unit is required to give meaning to the indicator.
- Sensitive: The sensitivity to stresses on the system must be perceptible and the response to stress, predictable.
- Coherent: All performance indicators must be coherent with the environmental policy of the organization.
- Representative: The environmental performance of the organization must be represented by the set of indicators defined.

In addition, in order to be "key", performance indicators must be also SMART meaning Specific, Measurable, Achievable, Relevant and Timely (Doran, 1981).

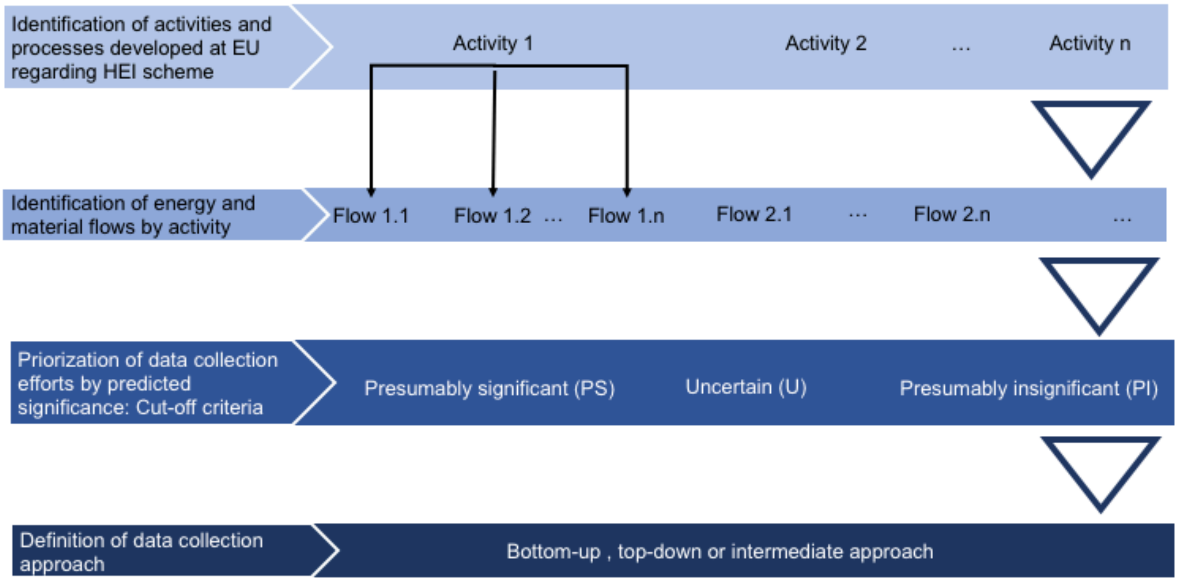
1.3 Reporting organization and reporting flows

Reporting organization is a concept described in O-LCA procedures as the unit to be studied (International Organization for Standardization, 2014). A reporting organization has clear and fix boundaries throughout all the study.

For HEIs, the environmental unit (EU) is proposed as reporting organization. An EU is an area that is physically localized, that has well-defined functions, and that controls at least one budget item related to material or energy flows. A HEI can be divided into several EUs. Each EU should have an interlocutor and should be internally and externally audited periodically through the application of any environmental procedure. Faculties, departments and research services are examples of EUs.

Once defined the reporting organization, reporting flows must be listed. According to the European Commission (2013), reporting flows should answer questions concerning 'what,' 'how much,' and 'how well?'. As noun, HEIs perform a social function and provide services as part of their activities ; there is not a formal product but the contribution to society through, education, research results and technology transfer. It is particularly challenging for these types of organizations to answer such questions (United Nations Environment Programme, 2015). Lo-Iacono-Ferreita et al., (2017b) suggested the scheme shown in figure 1.

Figure 1. Identification activities, processes and flows scheme (Lo-Iacono-Ferreira et al., 2017b)



2. Goals

The objective of this study is to analyze the use of CF as a KPI in HEI and propose a mechanism to include it in the KPI panel of the organization.

3. Methods

To achieve the goal proposed, the following method is used:

1) Development of state of the art of the environmental indicators related to CF applied in HEIs has been carried out through the study of the literature.
2) Proposal of a mechanism to introduce CF as a KPI in HEIs.
3) Case study of the application of CF in HEIs.

4. Results and discussion

For this study, three results are presented: the state of the art of the use of CF related indicators at HEIs, the proposal of a definition of a KPI for HEIs and the case study of its application.

4.1 State of the art

Prestigious organizations have defined several indicators related to CF, GHG emissions. Table 1 shows the indicators, units and their references where AASHE stands for The Association for the Advancement of Sustainability in Higher Education, GRI stands for Global Reporting Initiative and EEA stands for European Environment Agency. All the indicators shown are performance indicators (type B) under ABCDE classification indicators framework (European Environmental Agency, 2014).

Table 1. CF related indicators. Source: Lo-Iacono-Ferreira et al. (2018)

Indicator	Unit	Reference
Production and consumption of ozone depleting substances	tons	(EEA, 2014)
GHG emission trends	-	(EEA, 2014)
GHG emissions intensity	tons CO2e per EU*	(GRI, 2013)
GHG emissions	Points	(AASHE, 2016)
CO2 emissions per capita	tons	(UNEP, 2012; OECD, 2014, 2015; García-Sánchez, 2015; Moldan et al., 2012; Olszak, 2012)
Process to greenhouse gas emissions targets	-	(EEA, 2014)

Note: * FU stands for Environmental Unit.

Although there are no relevant references that evidence the use of CF as a KPI in HEI, the assessment of CF in these organizations is widely registered. Some examples are studies published by Robinson et al., (2017, 2018) Ramos et al., (2015), Lambrechts & Van Liedekerke (2014) Ozawa-Meida et al., (2013), and Roy et al., (2008).

Lo-Iacono-Ferreira et al. (2018) has proposed a set of environmental KPIs for HEI among which, the following related to GHG emissions are defined:

- GHG emissions of Scope 1 * by BUA
- GHG emissions from commuting by FTE student
- GHG emissions from commuting by FTE employee
- GHG emissions of Scope 3 * by FTE student

Where BUA refers to the physical dimension of the organization and represents a perfect unit of dimension of a traditional HEI measured in square meters and including all infrastructures green areas (classrooms, offices, common facilities, parking areas, gardens, etc.). And FTE students and FTE employees are assessed with equation 1 and 2 respectively.

$$FTE\ student = \frac{actual\ course\ load}{normal\ course\ load} \cdot \frac{actual\ duration\ of\ study\ during\ reference\ period}{normal\ duration\ of\ study\ during\ reference\ period} \qquad (1)$$

$$FTE\ employee = \frac{average\ hours\ worked}{average\ hours\ of\ a\ full{-}time\ worker} \qquad (2)$$

A full-time student is considered as a student taking 60 ECTS credits per year while a full-time worker has an average of 40 hours a week.

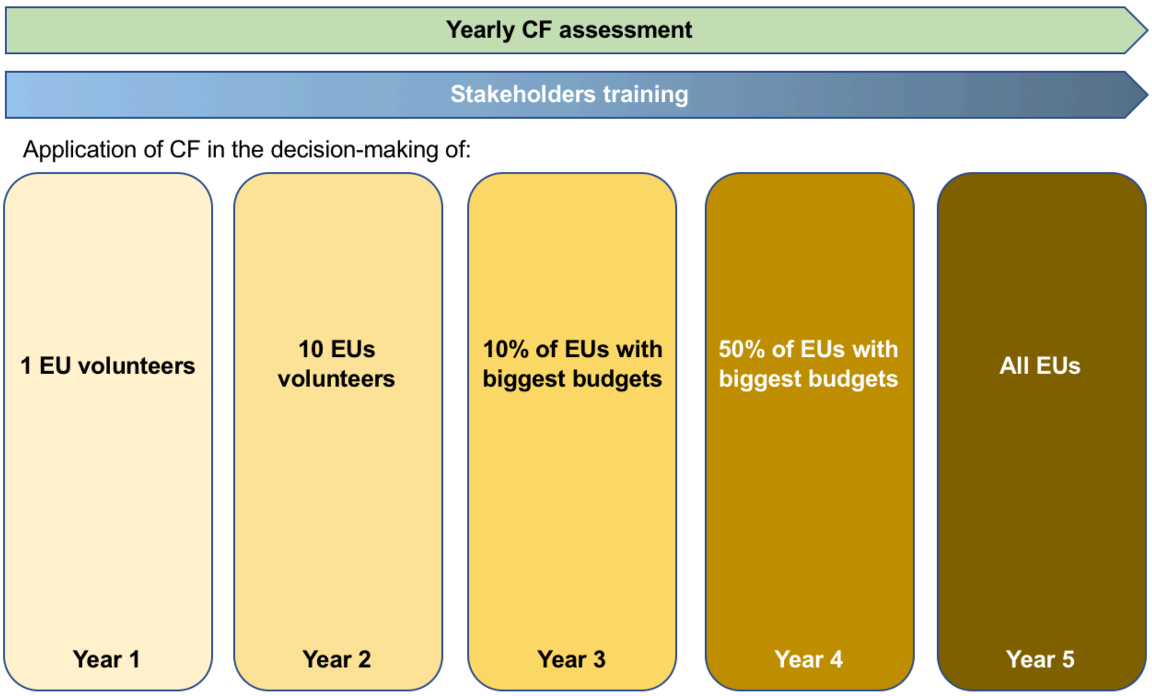
4.2 Mechanism proposal

In order to be able to assess CF, a structure as an environmental office is needed. HEIs with robust EMS (verified in EMAS) have a significant advantage as the structure required to collect periodically the information needed is already stablished. When presenting this study, EMAS register shows only 15 universities with EMS verified by EMAS distributed in, only, three campuses: Austria (7), Germany (5) and Spain (2). However, there is no reliable information regarding the use of CF as a KPI at these organizations.

To include CF as a regular KPI, beside a reliable assessment procedure, the commitment of the managers that are going to use this valuable information is required. Therefore, all members of the decision-making board should be trained in the meaning and scope of CF.

Rolling wave planning is suggested as the technic to introduce the KPI. It is a management technic that involves progressive elaboration to add details to the processes. Waves can be defined by annually. Figure 2 shows the suggested scheme of application.

Figure 2. Application scheme



The implementation time depends on the size of the organization. For a midsize organization with 40,000 students, 8,000 staff members, 700,000 m^2 and over 200 EUs, 5 years is a reasonable timing. Small HEIs may be able to complete the implementation in 3 years.

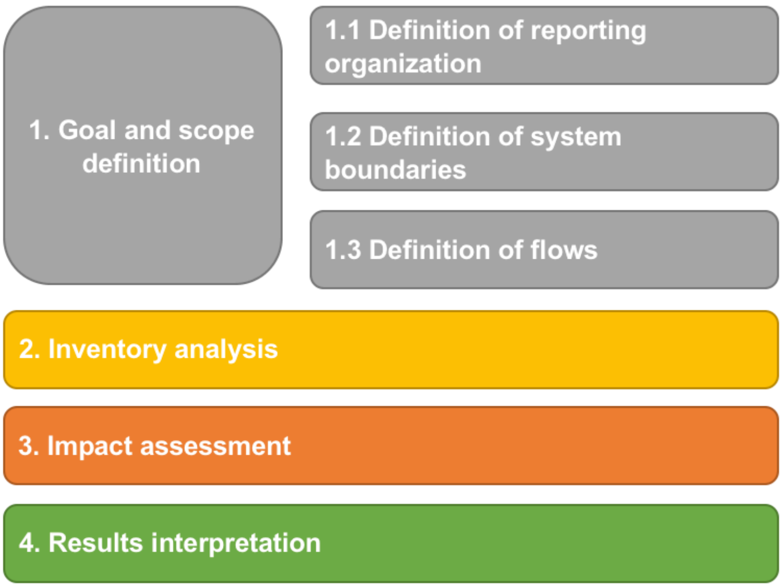
Regarding training, the university community has to be trained as a whole in the CF concept and its implications. However, the education of the management board of the EUs that will be activated each year is a priority.

The training cannot be limited to the university community but has to reach all stakeholders (i.e. suppliers, local government, campus neighbors, etc.) as some of the decisions based on a CF indicator might not be easy to accept or understand without the some basic knowledge.

The consensus on the assessment methodology is also essential for the success of the implementation of CF as a KPI. Four steps ISO methodology is proposed (figure 3). The reporting organization suggested, as previously described, is the EU.

A good definition of the EU is imperative for a correct use of CF as KPI. Impacts must be properly allocated and double counting must be avoided; meaning that the sum of CF has to correspond to the sum of EUs.

Figure 3. ISO methodology



System boundaries must be clearly defined to avoid double-counting impacts.

In order to have certainty regarding the flow definition, an identification of activities and processes is suggested. An expert panel including stakeholders might carry out the identification answering questions like what is and is not included in an EU must be made clear.

4.3 Case study: Universitat Politécnica de València (UPV)

Universitat Politècnica de València (UPV) is a public university located in the south east of Spain. It is organized in 14 faculties in three campuses with more than 32,5000 students and more than 8,000 employees.

UPV has an EMS verified by EMAS (registration number ES-CV-000030) that generates a yearly environmental declaration with relevant information regarding the environmental impact of the whole HEI disaggregated by campus. The environmental indicators assessed every year are:

- Energy efficiency. Direct consumption of electricity and fuels
- Renewable energy generated at UPV
- Electricity consumption
- Total water consumption disaggregated by tap and well water
- Curriculum greening
- Generation of non-hazardous waste disaggregated by paper and cardboard, light packaging and electrical and electronic waste
- Generation of hazardous waste
- Land use
- Emissions disaggregated by Carbon Footprint and hazardous gases
- Mobility
- Training and participation activities
- Communication

The environmental office is the responsible of the EMS and its verification since 2009. This office reports the environmental declaration and looks after the behavior of the HEI regarding its environmental policy. In 2016, the environmental office registered the CF of the whole HEI in the Spanish Register of Carbon Footprint. Currently, UPV only disaggregates its CF by campus in two scopes; 1 and 2. Scope 3 is not assessed. Figure 4 and 5 shows the CF of UPV from 2011 to 2017. Note that Vera campus located in Valencia gathers more than 200 EUs.

Figure 4. UPV Carbon Footprint (2011 - 2017). Scope 1

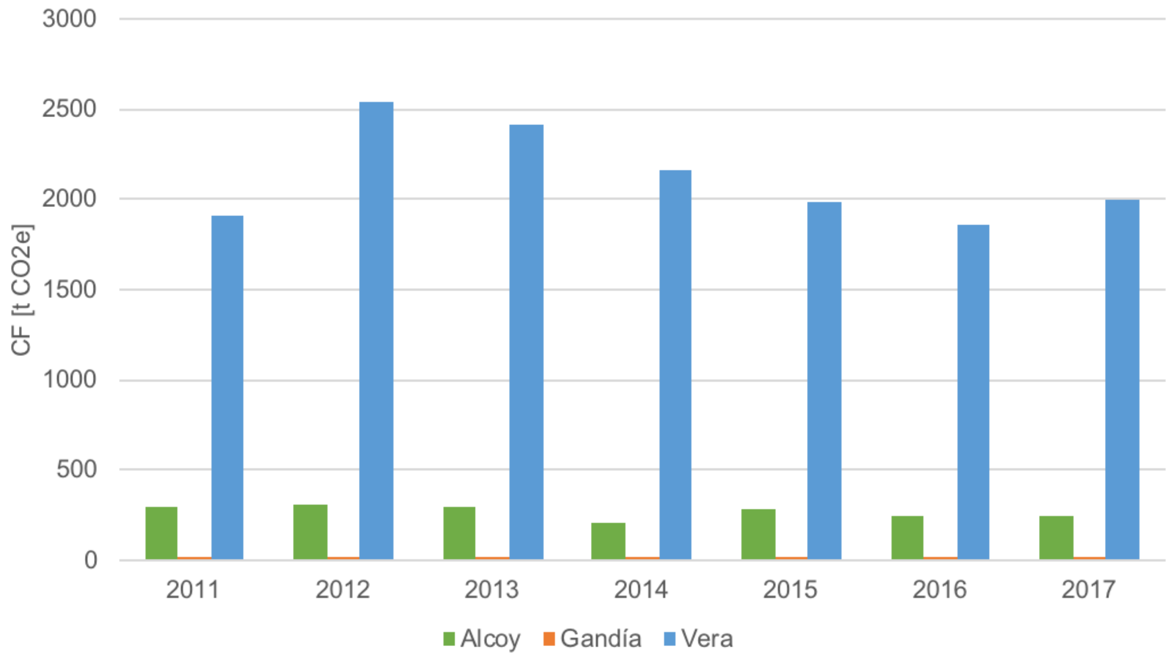
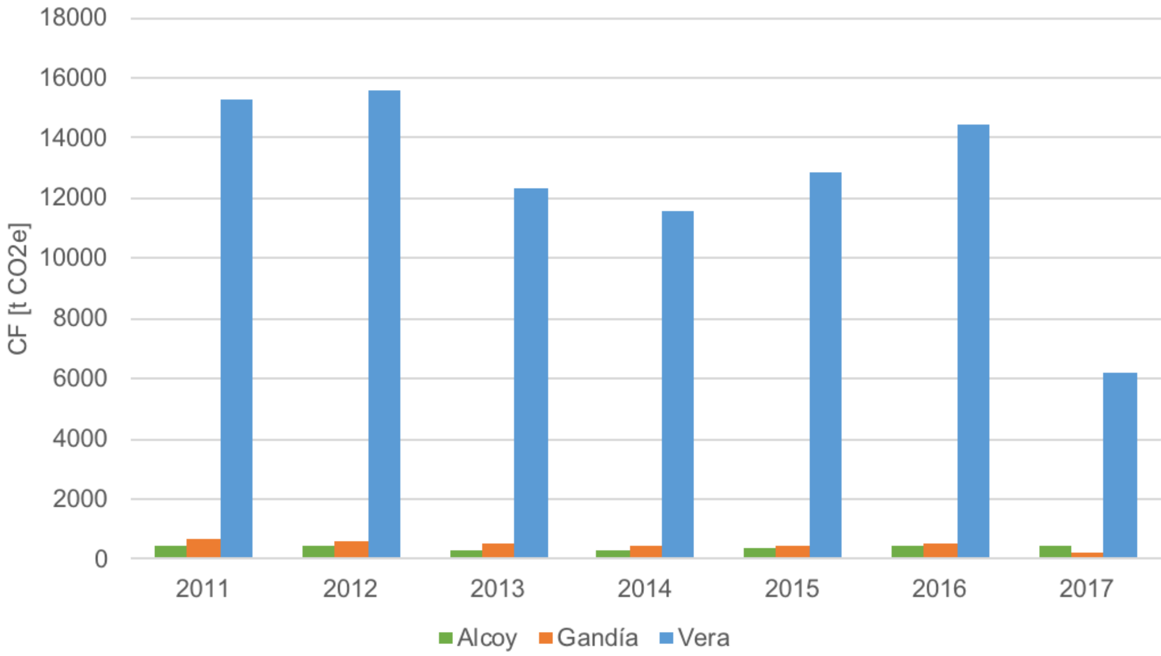


Figure 5. UPV Carbon Footprint (2011 - 2017). Scope 2



Escuela Politécnica Superior de Alcoy (EPSA) is one of the 211 EU of *UPV*. With 2,481 students and 293 employees in 2017, EPSA has its own campus organized in three buildings with a constructed surface of 28,717 m^2 and 1,270 m^2 of gardens. EPSA is proposed as the first volunteer EU for the implementation mechanism of CF as KPI as the research group participating in this paper its involved in a deeper analysis if CF for EPSA since 2011. Results of the assessment of CF considering FTE students, FTE employees and m^2 are shown in table 2 and 3. As it can be seen, CF at EPSA is a mature indicator ready to be used at a management level.

Table 2. CF of EPSA (2011 – 2017) Scope 1

	2011	2012	2013	2014	2015	2016	2017
t CO_2e /FTE students	0.15	0.15	0.13	0.09	0.13	0.13	0.11
t CO_2e /FTE employees	1.22	1.30	1.27	0.83	1.07	0.94	0.96
t CO_2e /BUA	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 3. CF of EPSA (2011 – 2017) Scope 2

	2011	2012	2013	2014	2015	2016	2017
t CO_2e /FTE students	0.23	0.22	0.15	0.14	0.18	0.22	0.20
t CO_2e /FTE employees	1.84	1.86	1.42	1.25	1.53	1.64	1.73
t CO_2e /BUA	0.02	0.02	0.01	0.01	0.01	0.01	0.02

In order to make the proposed mechanism work, the environmental office need to expand its CF assessment including the needed information to obtain the indicator:

- by FTE students, FTE employees and m^2
- by EU

The cost (economic, time and resource) of the first requirement is not significant as the information is easily available through the human resources office, the student register and the infrastructure registers. However, assessing CF by EU might require a significant investment. The purchase of fuel is ordered by equipment (boiler, engines, etc.) and can be assigned to an EU. But the electricity consumption is obtained from the information of the invoices that responds to the electric meters, one per campus. The use of additional meters in strategic places can help in the disaggregation of the information needed for the assessment.

The training and communication plan can be organized by the environmental office since the beginning of the implementation. Volunteers for year 2 can be recruit using EPSA as an example. Beside the volunteers participating in the first two years of implementation, the rest of EUs must be notify and train since the beginning of the process.

5. Conclusions

The following conclusions are highlighted:

- An office, environmental office, that coordinates training and assessment on CF is highly recommended.
- Although an EMS is not required, its structure helps feeding the assessment cycle of CF.
- Environmental units are the most adequate reporting organization as, properly applied, guarantee double accounting of impacts.
- The carbon footprint can be part of the set of key performance indicator, if it is properly assessed and interpreted.
- A rolling wave application scheme might help implementing the new KPI. It is a midterm project as the implementation time requires, at least, 3 years.
- Regarding the case study, the environmental office needs to introduce some assets and perform investments to be able to count with the environmental information needed to assess CF for all UPV EUs.

References

Altan, H. (2010). Energy efficiency interventions in UK higher education institutions. *Energy Policy*, *38*(12), 7722-7731. http://doi.org/10.1016/j.enpol.2010.08.024

Barnetson, B., & Cutright, M. (2000) Performance indicators as conceptual technologies. *Higher Education,* 40, 277–292. http://doi.org/10.1023/a:1004066415147

Bauler, T. (2012) An analytical framework to discuss the usability of (environmental) indicators for policy. *Ecological Indicators,* 17, 38–45. http://doi.org/10.1016/j.ecolind.2011.05.013

Bonaccorsi, A., Daraio, C., Lepori, B., & Slipersæter, S. (2007) Indicators on individual higher education institutions: addressing data problems and comparability issues. *Research Evaluation,* 16(2), 66–78. http://doi.org/10.3152/095820207X218141

Doran, G.T. (1981) There's a S.M.A.R.T way to write management's goals and objectives. IIMB Management Review, 70(11) 35-36 Retrieved on June 15th 2016 from http://community.mis.temple.edu/mis0855002fall2015/files/2015/10/S.M.A.R.T-Way-Management-Review.pdf

European Commission (2013) European Commission Organization Environmental Footprint Guide. European Commission - Joint Research Centre - Institute for Environment and Sustainability. Retrieved on June 1st 2016 from http://eur-lex.europa.eu/JOHtml.do?uri=OJ:L:2013:124:SOM:EN:HTML

European Environment Agency (2014) Digest of EEA indicators. Luxembourg. Retrieved on July 1st 2016 from http://www.eea.europa.eu/publications/digest-of-eea-indicators-2014

European Environment Agency (2014) Digest of EEA indicators. Luxembourg. Retrieved on July 1st 2016 from http://www.eea.europa.eu/publications/digest-of-eea-indicators-2014

García-Sánchez, I. M., Almeida, T. A. D. N., & Camara, R. P. D. B. (2015) A proposal for a Composite Index of Environmental Performance (CIEP) for countries. *Ecological Indicators,* 48, 171–188. http://doi.org/10.1016/j.ecolind.2014.08.004

Global Reporting Initiative (2013) G4 Sustainability Reporting Guidelines. Global Reporting Initiative. Retrieved on March 1st 2016 from https://www.globalreporting.org/resourcelibrary/G4-Package.zip

International Organization for Standardization (2013a) Greenhouse gases -- Carbon footprint of products -- Requirements and guidelines for quantification and communication. ISO 14067:2013

International Organization for Standardization (2013b) Environmental Management – Environmental Performance Evaluation – Guidelines. International Organization for Standardization

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

Kerzner, H.R. (2011) Project Management Metrics, KPIs and Dashboards: A guide to Measuring and Monitoring Project Performance. Ed. John Wiley & Sons, Inc. http://doi.org/10.1002/9781118086254

Lambrechts, W., & Van Liedekerke, L. (2014). Using ecological footprint analysis in higher education: Campus operations, policy development and educational purposes. *Ecological indicators*, *45*, 402-406. https://doi.org/10.1016/j.ecolind.2014.04.043

Lo-Iacono-Ferreira, V., Torregrosa-López, J. I., & Capuz-Rizo, S. F. (2017a). The accounting system as complementary data source for Organizational Life Cycle Assessment of Higher Education Institutions. In *21st International Congress on Project Management and Engineering. Cádiz. 12th–14th July* (Vol. 2017). https://goo.gl/Asc384

Lo-Iacono-Ferreira, V.G., Torreogrsa-López, J.I., Capuz-Rizo, S.F. (2017b) Organizational Life Cycle Assessment: suitability for Higher Education Institutions with Environmental Management System. International Journal of Life Cycle Assessment. 1-6 http://doi.org/10.1007/s11367-017-1289-8

Lo-Iacono-Ferreira, V. G., Capuz-Rizo, S. F., & Torregrosa-López, J. I. (2018). Key Performance Indicators to optimize the environmental performance of Higher Education Institutions with Environmental Management System–A case study of Universitat Politècnica de València. *Journal of Cleaner Production*. 178, Volume 178, p846-865 https://doi.org/10.1016/j.jclepro.2017.12.184

Moldan, B., Sková, S J., & Charles, T. s H. (2012) How to understand and measure environmental sustainability: Indicators and targets. *Ecological Indicators*, 17, 4–13. http://dx.doi.org/10.1016/j.ecolind.2011.04.033

Olszak, E. (2012) Composite indicators for a sustainable campus - Design rationale and methodology: The case of the Catholic Institute of Lille. *Ecological Indicators*, 23, 573–577. http://doi.org/10.1016/j.ecolind.2012.05.021

Ozawa-Meida, L., Brockway, P., Letten, K., Davies, J., & Fleming, P. (2013). Measuring carbon performance in a UK University through a consumption-based carbon footprint: De Montfort University case study. *Journal of Cleaner Production*, *56*, 185-198. https://doi.org/10.1016/j.jclepro.2011.09.028

Pelletier N., Allacker K., Pant R., Manfredi S. (2014) The European Commission Organisation Environmental Footprint method: comparison with other methods, and rationales for key requirements. The International Journal of Life Cycle Assessment, 19(2), 387–404. http://doi:10.1007/s11367-013-0609-x

Ramos, T. B., Caeiro, S., Van Hoof, B., Lozano, R., Huisingh, D., & Ceulemans, K. (2015). Experiences from the implementation of sustainable development in higher education institutions: Environmental management for sustainable universities. *Journal of Cleaner Production*, *106*, 3-10. https://doi.org/10.1016/j.jclepro.2015.05.110

Robinson, O. J., Kemp, S., & Williams, I. D. (2017). Consumption, production… or perfection? Exploring approaches to carbon footprinting in higher education institutions. In *Handbook of Theory and Practice of Sustainable Development in Higher Education* (pp. 441-452). Springer, Cham. https://doi.org/10.1007/978-3-319-47889-0_31.pdf

Robinson, O. J., Tewkesbury, A., Kemp, S., & Williams, I. D. (2018). Towards a universal carbon footprint standard: a case study of carbon management at universities. Journal of Cleaner Production, 172, 4435-4455. https://doi.org/10.1016/j.jclepro.2017.02.147

Roy, R., Potter, S., & Yarrow, K. (2008). Designing low carbon higher education systems: Environmental impacts of campus and distance learning systems. *International journal of sustainability in higher education*, *9*(2), 116-130. https://doi.org/10.1108/14676370810856279

Smeets, E., & Weterings, R. (1999) Environmental indicators: Typology and overview. Copenhagen. Retrieved on June 1st 2012 from http://www.eea.europa.eu/publications/TEC25

Tao Gao, Qing Liu, Jianping Wang; A comparative study of carbon footprint and assessment standards, *International Journal of Low-Carbon Technologies*, 9, 3: 1 September 2014, P237–243, https://doi.org/10.1093/ijlct/ctt041

The Association for the Advancement of Sustainability in Higher Education. (2016) stars Technical Manual. Version 2.1. Retrieved on July 1st 2016 from http://www.aashe.org/files/documents/STARS/stars_2.1_technical_manual_-_administrative_update_one.pdf

Torregrosa-López, J. I., Lo-Iacono-Ferreira, V., Martí-Barranco, C., & Bellver-Navarro, C. G. (2016). The strengths of EMAS as an environmental management system for European university campuses. *International Journal of Environment and Sustainable Development*, *15*(1), 89-106. https://doi.org/10.1504/IJESD.2016.073339

United Nations Educational Scientific and Cultural Organization, 2014. Education: Enrolment by Level of Education. Retrieved on April 1st 2018 http://data.uis.unesco.org/index.aspx?queryid¼142&lang¼en

United Nations Environment Programme (2015) Guidance on Organizational Life Cycle Assessment. Life-Cycle Initiative, United Nations Environment Program and Society for Environmental Toxicology and Chemistry, Paris, France. Retrieved on June 1st 2016 from: http://www.lifecycleinitiative.org/wp- content/uploads/2015/04/o-lca_24.4.15-web.pdf

Weidema BP, Thrane M, Christensen P, Schmidt, J.and LØkke, S. Carbon footprint. A catalyst of Life Cycle Assessment Journal of Industrial Ecology 2008;12:3–6. http://doi.org/10.1111/j.1530-9290.2008.00005.x

Zaman, A. U. (2014). Identification of key assessment indicators of the zero waste management systems. *Ecological Indicators*, 36, 682–693. http://doi.org/10.1016/j.ecolind.2013.09.024