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Organizational Life Cycle Assessment: Suitability for Higher Education Institutions with Environmental Management Systems.

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Abstract
Purpose
The purpose of this study is to analyze the suitability of organizational life cycle assessments (O-LCAs) for higher education institutions (HEIs) with special attention to the benefits and particularities of those adopting environmental management systems (EMSs) verified according to EMAS.
Methods
A thorough analysis following ISO/TS 14072 and UNEP Guidance was carried out using the Universitat Politècnica de València (UPV) EMS verified by the EMAS for guiding principles to develop the methodological proposal. The self-sufficiency of UPV EMS for developing an O-LCA was tested at the university pilot unit. The four steps of the O-LCA were applied to the pilot.
Results and discussion
A reporting organization, the organization to be studied (boundaries and scope), was defined in consideration of the environmental units (EU) of the EMS. Operational control was selected as a consolidation method. Reporting flows and system boundaries are also discussed. A three-scope scheme of the GHG protocol is introduced and combined with the ISO 14072 boundary definition to support better alignment with the HEI structure.
For the life cycle inventory analysis, a mechanism for identifying activities and processes as well as their material and energy flows is proposed in consideration of the particularities of HEIs. A procedure for the prioritization of data collection efforts and cut-offs was developed. The procedure integrates current EMAS actions based on the significance of environmental aspects combined with the influence of reporting organizations under their control.
Impact categories focus on midpoint indicators along with an additional inventory level indicator as part of the life cycle impact assessment (LCIA). Unfortunately, due to a lack of quality data available, LCIA can only be assessed in part with little interest in outcomes. Partial results are presented.
Conclusions
An EMS verified by EMAS is proven to be useful in the assessment of O-LCA for HEIs. However, EMAS requirements do not ensure the availability of all data needed to develop an O-LCA. An accounting system should complement a lack of data if it is properly structured. Considerable efforts are required to obtain an accurate result. EMS and the accounting system may be able to provide information that supports an O-LCA approach based on a coherent prioritization of data collection efforts and cut-off procedures along with a set of justified impact category indicators. Overall, organization managers must be in favor of such an assessment to meet the requirements of successful implementation.

Keywords: Organizational Life Cycle Assessment; Higher Education Institutions; Environmental Assessment; University; Life Cycle Inventory; Life Cycle Impact Assessment;

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List of acronyms
CDP: Carbon Disclosure Project
EA: Environmental Aspect
EAS: Environmental Aspect State
EC: European Commission
EMAS: Environmental Management and Audit Scheme
EMS: Environmental Management System
EPSA: Higher Polytechnic School of Alcoy (Escuela Politécnica Superior de Alcoy in Spanish)
EU: Environmental Units
GHG: Greenhouse Gases
HEIs: Higher Education Institutions
ISO: International Standard Organization
LCA: Life Cycle Assessment
LCI: Life Cycle Inventory
LCIA: Life Cycle Impact Assessment
O-LCA: Organizational Life Cycle Assessment
OEF: Organizational Environmental Footprint
UNEP: United Nations Environment Program
UPV: Universitat Politècnica de València

1 Introduction

The launch of the Technical Specifications (TS) of the International Standards Organization (ISO), ISO/TS 14072 (ISO 2014a) aims to address a gap in the standard methodology for assessing the impacts of the activities of organizations along their life cycles. An organization, according to ISO/TS 14072, is defined as a group of people who have their own functions with the responsibility, authority and relationships needed to achieve the group's objectives. Assessing the life cycle of organizations has been more difficult than the traditional life cycle assessment (LCA) of products or services because some definitions can be challenging to formulate (e.g., functional units or system boundaries).
Some initiatives that have preceded organizational life cycle assessment (O-LCA) include the GHG Protocol Corporate, Bilan Carbone, Carbon Disclosure Project (CDP), Organizational Environmental Footprint (OEF) recommendations of the European Commission (EC) and ISO 14046. An in-depth comparison can be reviewed in Pelletier et al. (2014). The benefits of a life cycle perspective for organizations have also been discussed and proven (Hellweg and Milà i Canals 2014); it can be highlighted that it:

- gives a complete and accurate account of the impact of what is being assessed,
- allows for a better management of resources while providing key information on the needs of the object of study and,
- encourages fruitful communication with suppliers, clients and stakeholders in general.

O-LCA is a life cycle approach for addressing the environmental footprint of organizations (UNEP 2015). The scope definition and inventory assessment of O-LCA, in requiring a solid definition of the reporting organization and reporting flows, differ significantly from those used under a traditional LCA procedure. The strong recommendation to not use O-LCA for comparative purposes constitutes its other significant difference from LCA (Martínez-Blanco et al. 2015a). The O-LCA approach provides organizations with a guide for identifying and quantifying environmental aspects within and beyond the boundaries of an organization while considering stakeholders' interests. It is considered a multi-impact environmental approach, as it analyzes environmental issues relevant to an organization while providing a potential environmental impact profile of its activities. Environmental impact profiles provide relevant information needed to disclose environmental insights on an organization's decision-making process. O-LCA can also be used to forecast scenarios and to stimulate data collection efforts (UNEP 2015; Martínez-Blanco et al. 2015b). In particular, ISO/TS 14072 highlights the identification, evaluation and interpretation of the significance of environmental aspects (EA) related to the management systems of organizations as defined under ISO 14001 (ISO 2004). As another relevant benefit, O-LCA can be used to track the environmental performance of an organization and benefits linked to decision-making processes, as the method can be used to generate relevant information. The delivery of reporting guidance and transparent policies are no less relevant benefits that come with O-LCA implementation.
In this paper, we study HEIs, particularly those with an environmental management system (EMS) verified under the EMAS referred to as the Eco-Management and Audit Scheme (EC 2016). As the EMAS is based on ISO 14001, this certification does not guarantee compliance with O-LCA requirements. In particular, three exclusive features of the EMAS can be highlighted, providing a framework for the identification of significant aspects, for the identification of opportunities for improvement and for the reporting process:

- a commitment to continual improvement,

- the involvement of organization managers through manager reviews and,
- openness and transparency and the periodic delivery of environmental information to interested parties.

HEIs have a strong effect on the future managers of our industries and countries (Disterheft et al. 2012, Lozano et al. 2006, 2011). As lighthouses of future society, leading by example is their duty (Cortese 2003, Watkins and Glover 2016). HEIs with EMSs verified under EMAS have shown an advantage over organizations that lack EMSs when conducting environmental assessments. The EMAS has proven to be a robust guide to the HEI EMS due to its adaptability to the inner complexities of these types of organizations. However, EMSs focus on the on-site activities of organizations, resulting in incomplete study from an LCA point of view. The authors believe that the O-LCA approach and its relationship to a robust EMS deserves special attention, as this may provide valuable information and a strong case for including a life cycle approach in the daily environmental assessment of HEIs.

Universitat Politècnica de València (UPV) is one of the largest HEIs that has verified its EMS through the EMAS. For a description of EMAS implementation at UPV, see Torregrosa-López et al. (2016). The existence of an EMS might create enough structure to address O-LCA through what UNEP defines as *pathway 2*, a scenario in which an organization already employs a gate-to-gate environmental approach (see the section entitled "Specific situations for the implementation of O-LCA" in (UNEP 2015) for more details). Although UPV uses a system that assesses its environmental performance to some degree, O-LCAs should provide additional improvements that complement the existing EMS. Another possible pathway is number 4, which was developed for organizations that assess their environmental performance based on environmental indicators. UPV assesses its carbon and ecological footprint yearly. However, the authors note that for an initial approach through which there is no full understanding of where the most significant impacts are, using these indicators and reports as bases of an O-LCA increases bias risks. Although the EMS is the data source for these studies, the scope does not need to be the same as that of an O-LCA as proposed by UNEP. Therefore, under a first approach, we consider *pathway 2* to be more appropriate. With further iterations of O-LCA to be developed in future years, the integration of reports and environmental indicators may prove valuable.

The aim of this study is to analyze the applicability of O-LCA to particular organizations (HEIs) that employ robust EMSs verified under the EMAS that generate a defined flow of information on environmental performance. The UPV EMS verified according to the EMAS is used as an example as it has been used for more than 7 years, proving its verification. Critical decisions regarding O-LCA application are suggested as part of a methodological proposal. The methodology is applied to one environmental unit (EU) of UPV (described further in this paper), and it represents a pilot method highlighting the strengths and weaknesses of UPV's EMS while answering the following question: is an EMS verified under the EMAS guaranteed success in O-LCA development?

A literature review of O-LCA for organizations and a description of the method used in this study are provided below.

1.1 Literature review of O-LCA for organizations

As the O-LCA approach is relatively new, the related literature is not abundant. Aside from ISO standard ISO/TS 14072 (ISO, 2014a) *Requirements and guidelines for Organizational Life Cycle Assessment*, the UNEP Guidance on Organizational Life Cycle Assessment (UNEP 2015) is a publication focused on O-LCA. Life Cycle Initiative (2016) is the organization that coordinates all O-LCA flagship initiatives. Martínez-Blanco (2015b, 2015c) reports on the progress of this project and discussed O-LCA. Jolliet et al. (2014) delves into a definition of life cycle impact categories with particular attention to organizations. Although there are no relevant publications focused on O-LCAs for HEIs, some approaches related to industrial sectors have been published, e.g., an exploration of system boundaries for the O-LCA of beverage-packaging companies by Manzardo et al. (2016) and a decision-making process based on O-LCA methodologies for the textile sector by Resta et al. (2016).

Even though O-LCA is not yet a widely used concept, for some time now researchers and organization managers have been using an LCA point of view to assess the environmental performance of organizations (Finkbeinar et al. 1998), e.g., the Overall Business Impact Assessment applied to Unilever (Tyler and Postethwaite 1996; Clift and Wright 2000) and Input-Output Analysis (Lave et al. 1995; Huang et al. 2009). UNEP guidance on O-LCA considers all of these approaches. One study of HEIs concerns the university examined in this paper, UPV, as described by Lo-Iacono-Ferreira et al. (2011; 2016).

By contrast, the implementation of EMSs in HEIs has been widely studied, e.g., ISO 14001 and the EMAS (Disterhelft et al. 2012; Tlapa et al. 2009; Torregrosa-López et al. 2016).

In light of this review, an analysis of the suitability of O-LCA for HEIs has not yet been conducted. In addition, a robust EMS operated within a complex organization as an HEI promises advantages for the development of environmental assessments such as O-LCA that deserve to be explored.

1.2 Methods

To study the suitability of O-LCA for HEIs, an in-depth analysis of ISO 14072 and UNEP Guidance has been performed. The corresponding results are presented according to ISO methodology through the following sections:

1. Goals and scope.
    1.1. Reporting organization.
    1.2. Reporting flows and system boundaries.
2. Life Cycle Inventory analysis (LCI).
3. Life Cycle Impact Assessment (LCIA).
4. Results interpretation.

Each point is discussed based on the HEI framework. Proposed guidance on application is provided as a methodological proposal. The application of the proposed methodology to an EU of UPV as a pilot is described, applied to the extent possible, and discussed. Special attention is paid to synergies between O-LCA and the EMAS-verified EMS of UPV.

2 Methodological proposal

In this section, each step of O-LCA is analyzed, defined and discussed as comprehensively as possible. A thorough analysis of both O-LCA and EMAS requirements and operations serves as basis of the hypothesis of this study: HEIs with an EMS verified under the EMAS possess a solid structure for addressing an O-LCA. Most O-LCA requirements outline a direct solution through the EMAS. However, some issues such as data quality requirements and the selection of impact categories are not explicitly referenced in the EMAS and may constitute an issue. A detailed comparison between both tools can be found in Annex 1.

The methodological proposal is based on the particularities of HEIs and in consideration of the functioning of an EMS and particularly of an EMAS.

2.1 Goal and scope

To define the goal and scope of an assessment, UNEP suggests answering the following questions. “What do you want to assess?” “Who will use the results?” “What questions are you trying to answer?” The objective is to identify organization to be studied; the reporting organization concerned; the consolidation method used; considered operations, facilities and sites of the studied organization; reporting flows; allocation procedures (if needed); impact assessment methodologies; and impact and data quality requirements while making all limitations of the assessment clear.

2.1.1 Reporting organization

As the functional unit of LCA, the reporting organization represents the unit to be assessed. Limits must be identified and held consistent throughout the entire process. Units that may disaggregate the reporting organization can be explored by examining the HEI EMS concerned, i.e., departments or environmental units (EU).

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. Any HEI can be divided into EUs. Each EU should have an environmental interlocutor and should be internally and externally audited periodically through the given EMS. Faculties, departments and research services are examples of EUs. When initially conducting an O-LCA, it is suggested that one EU is used as a pilot, as EUs have clear limits and can remain consistent throughout an assessment. An HEI could be assessed as a reporting organization divided into EUs. The sum value of the O-LCA for all EUs should represent the O-LCA of the HEI as a whole. By integrating the assessment method with the EMAS structure, scaling up should be easy to carry out once all sources of information are correctly managed.

The use of EUs constitutes a benefit that the EMAS can offer when carrying out an O-LCA of an HEI. Of course, any HEI can define its EUs; however, the EMAS ensures the structure needed for definition, as the whole organization can be systematically reviewed. The EU is a concept that was developed by UPV during the execution of its EMS. Although it is not described under EMAS rules, it was validated by the EMAS during the verification of the UPV EMS in 2009 (Registration Code: ES-CV-000030).

An alternative to assessments based on EUs involves considering a whole HEI as a reporting organization - a black box - and not going into detail on internal flows. This is a valid alternative approach when no EMS is available, but when a robust system can provide detailed information through consideration of an EU, it seems to be good practice to take advantage of this. Disaggregated information adds value to the interpretation of results and therefore to the decision-making processes in which this information takes part. In further iterations of the assessment, some feasible simplifications might come to light.

It is important to not forget that an O-LCA study must follow a clear consolidation method and reference period. If any changes between two consecutive studies occur, they must be reported, detailed and analyzed to avoid misunderstandings and to generate an assessment that reflects reality. As an EMS is

based on an operational control scheme and works on annual reporting basis, the consolidation method suggested is the operational control and the reference period covers one year.

2.1.2 Reporting flows

According to EC (2013), reporting flows should answer questions concerning 'what,' 'how much,' and 'how well?' HEIs perform a social function and provide services as part of their mission; they do not produce a formal product. As observed by UNEP (2015), it is particularly challenging for these types of organizations to answer such questions.

The mission of HEIs, or the final goal of these organizations, is dependent on the nature of the institution (public, private, research and/or technology transfer-oriented, etc.). In any case, this is not within the scope of the present analysis. Functional units for HEIs were discussed in the literature prior to the launch of the O-LCA method: students in regards to education; articles published on research and profits for technology transfer (Lo-Iacono-Ferreira et al., 2016). According to these findings, the number of equivalent students is recommended as the reporting flow for HEIs. The equivalent student unit is defined as a full-time student, and it is somehow already part of an EMS verified under the EMAS. On one hand, the EMAS requires the normalization of environmental indicators based on the number of full-time equivalent employees. Therefore, the procedure used to assess full-time equivalent persons is already incorporated within the system. On the other hand, the EMAS requires the description of activities, processes and services; the number of students involved is a basic measure that must be reported when the organization concerned is an educational institution.

Lo-Iacono-Ferreira et al. (2016) found a direct relationship between equivalent students and environmental indicators (the ecological footprint) for universities. Moreover, this unit expresses the main goal of HEIs: to teach and train students. This is why the number of equivalent students is considered to be a good source of reporting flow. However, consistency analyses and results of the first approach to O-LCA must verify that the selection of equivalent students in reporting flows is appropriate.

2.1.3 System boundaries

System boundaries must be clearly defined to avoid double-counting impacts. For a successful identification of activities and processes, what is and is not included in an EU must be made clear. Are other EUs related to the one under analysis? How do they interact? The structure of an HEI as a whole must be carefully defined. For example, UPV runs 14 faculties and schools, 44 departments, 35 research facilities, more than 90 university services and almost 30 facilities operated by third parties (full details can be found in Torregrosa-López et al. 2016). Departments are physically located within faculties. The energy consumption and waste generation of these facilities is managed by faculties with operational control. However, each department purchases its own supplies (office materials, computers, lab equipment and supplies, etc.). Faculties have no control over these supplies.

System boundaries shall reflect the consolidation approach used when assessing organizations (ISO 2006b). Therefore, an operational control boundary is recommended to taking advantage of the scope of an EMS verified under the EMAS. The EMS shall establish objectives and targets that allow for the identification and monitoring of all EAs related to the operations (activities, processes and services) of the organization.

For a more complete definition of the system boundaries, an extension of the three scopes considered by the GHG Protocol Corporate Standard to other environmental issues apart from GHG emissions is proposed for HEIs and is used for the pilot as suggested by Draucker (2013) and Braunschweig (2014):

(1) Direct resource use, emissions and waste are included under Scope 1,

(2) Upstream indirect factors are divided into two scopes:

- Scope 2: indirect emissions and resources associated with infrastructure usage, i.e., power production,
- Scope 3: all other indirect emissions and forms of resource use, i.e., emissions associated with waste and waste water treatment,

(3) Downstream indirect factors are not considered, as HEIs are service providers.

2.2 Life Cycle Inventory analysis (LCI)

The application of a robust EMS with ISO 14001 certification or EMAS periodic verification (or both as is the case for UPV) supports valuable expertise needed to define an LCI. The following procedure is recommended as a way to ensure the consideration of all flows once the reporting organization's goals and scope are well defined. Fig. 1 shows the scheme of this procedure.

An iterative loop is included under the procedure, as data collection, data validation and consistency analyses can reveal deficiencies in the identification of activities or flows.

2.2.1 Identification of activities and processes

EUs and scopes are defined at the Goals and Scope definition stage. Regarding the scopes used, a careful analysis must be conducted to determine which activities and processes are direct activities and which are

indirect—upstream or downstream—activities. Additionally, extra care must be taken to avoid double counting EUs that may have shared input or output flows.
Activity and process identification is an EMAS requirement, and therefore an EMS shall employ tools used to update the list of operations annually. The most common tools used include internal surveys, expert advice and facilitated workshops. It is suggested that activities and processes mentioned during identification that are allocated outside of the EU remain clearly identified at the final study reporting stage, as such information can prove valuable for subsequent studies of the same EU. A broader O-LCA can be developed from EU assessments if integration carefully avoids double counting and omissions.
As HEIs do not have a product, there are no easily recognized downstream activities. The role of graduates' professional activities has been broadly debated. This is a relevant issue for the analysis of green curricula, as the result of a good environmental education can be reflected in good professional practices. It may be interesting to consider this aspect when assessing an EU that involves teaching activities. If HEIs are assessed as a whole, other interesting aspects become involved in relation to downstream activities other than curricula, e.g., environmental aspects of research results. These aspects require extensive analysis and debates between experts on these subjects.

2.2.2 Identification of energy and material flows by activity

The individual identification of flows is needed for a rigorously defined LCI. Although data are obtained from an accounting system or EMS and no allocation procedure is applied, as EUs are treated as a whole, identifying flows for each activity can help ensure that all material and energy flows are considered.
Primary data are required to measure direct emissions and resources and are suggested as the most appropriate for studying indirect emissions and resources. Sources include emissions measurements and waste composition analyses inherent to the EMS and other sources such as invoices of purchases and stock inventories that may be part of an EMS or not. Whenever possible, the source should be the EMS, as it works with material units (kg, kW, etc.) rather than budgets that register monetary units. When an EMS integrates supplier and service registration, this source gains relevance during assessment. Budgets may be used as a consistency check tool or as a secondary source of information, as they require a conversion of units that adds uncertainty to the assessment.
Regarding general sources, at the time of publishing this study, no scientific papers with generic data on LCA for HEIs have been published. However, other HEI environmental assessments related to carbon, water and ecological footprints can be used as alternative sources, although such data must be handled with care in regards to reliability and coherency (scope, method, geolocation, etc.). Some government statistics for the educational sector may also be useful.
The use of databases such as Ecoinvent, EPLCA, etc. is foreseen as they can complement information given by the EMAS. Energy and basic materials (e.g., water) can be studied in consideration of their complete life cycles. Other materials such as the raw materials needed to produce office supplies might only be considered through an initial O-LCA if existing and accessible databases include such information. Otherwise, risks of assessment failure increase significantly. A simplification can prevent analysis paralysis. It must also be considered that cut-off criteria might exclude some inputs affected by such weaknesses. A prioritization and cut-off methodology is proposed and discussed further in this section. However, every full or partial omission must be reported on and justified. The use of simplifications does not mean that an assessment is not valid if it is properly explained and transparently reported. Higher levels of quality and greater specificity should be expected in a next iteration of this O-LCA.

2.2.3 Definition of data collection approaches

ISO/TS 14072 can involve three different approaches:

- Bottom-up, where LCA involves adding and weighing products together with supporting activities.
- Top-down, where the reporting organization is considered as a whole and where inputs and outputs are added.
- Hybrid approach that combines bottom-up and top-down models to compose a data collection scheme.

No products have been designed for HEIs. Therefore, gathering existing LCAs through a bottom-up approach is not possible. A top-down approach seems the most reasonable option for HEIs.

2.2.4 Prioritization of data collection efforts by predicting significance: Cut-off criteria

The proposed prioritization and cut-off criteria aim to consider activities, processes and EAs based on relevance. The upgraded prioritization procedure considers both the quantitative relevance of EAs and the influence of an EU on the control of activities or related processes. Prioritization procedures are designed to optimize human and economic resources. Activities and processes generating higher scores require fewer resources to obtain a better outcome than activities or processes generating lower scores.
On one hand, activities and processes can be prioritized while bearing in mind an EU's capacity to influence resource use and emissions according to GRI (2005) and WRI and WBCSD (2011). For HEIs, a scoring procedure is proposed. This proposal responds to experience gained through the implementation

and management of EMSs. On the other hand, the EMAS encourages EMSs to categorize all organization EAs as (S) significant or (NS) insignificant. At UPV, this latter procedure is referred to as the Environmental Aspect State (EAS). However, the potential influence of an organization on its operational control over activities or processes related to EAs is not considered as suggested by GRI (2005) and WRI and WBCSD (2011). This is why an upgraded prioritization procedure is proposed. The complete prioritization procedure is outlined in Fig. 2 and is described below.

As a first step, EAs are defined and classified according to the EAS of an organization as S or NS. Alongside this, activities and processes detected through LCI analysis are also classified by the degree of control that an EU has over them, generating an activity property referred to as the Control State (CS). The CS has three possible definitions: complete control (CC), partial control (PC) and uncontrollable (UC). CC denotes complete control where an EU has operational control over an activity or process. PC denotes a certain level of uncertainty regarding an activity due to partial operational control, i.e., outsourcing. UC refers to those activities over which an EU has no influence. When any UC activities are detected, they must be thoroughly analyzed and reported on while considering that the chosen consolidation method involves operational control.

The iterative loop of the LCI procedure (Fig. 1) can highlight flows and activities not considered in the initial analysis stage. The UC state also works as a consistency mechanism for the entire LCI analysis. When a UC is detected, the identification of activities and of its flows must be reviewed. These uncontrollable activities may be significant and require action in order to become controllable.

Once the EAS and CS are assessed, a crosscheck assigns a score to each EA for each activity and process. The total score by activity and process generates a prioritized list (in descending order; highest first) that can be used to assign resources and efforts for assessment. This method is compatible to a top-down data collection approach. The data collection approach involved is discussed further in this section. Table 1 shows the rules governing crosscheck score assignment.

Once the prioritized list is fixed, the cut-off criterion is applied. For HEI assessment, an extended cut-off criterion is proposed as a way to facilitate the development of initial approaches to O-LCA. The extended cut-off criterion involves addressing the accumulated percentage score for each subject of study: activities and processes as top-down approaches used. When a subject of study (activity, process or EA) exhibits a high level of control, actions taken by an EU to address improvements in its environmental performance would be more efficient. Similarly, when the subject of study is S, any improvements would reflect a broader difference in the environmental performance of an EU than when an NS subject is considered. Therefore, there is a direct relationship between the score obtained when considering significance and control levels and the impact of a certain subject of study.

A cut-off of between 90% and 95% of the score accumulated under a first O-LCA approach is recommended. The cut-off sets aside the lower 10% or 5% of the subjects studies. This proposal is based on the various simplifications typically applied in product-based LCAs (Fleischer et al. 2001; Hochschorner and Finnveden 2003; Vivancos Bono, J.L. 2005).

The remaining subjects must be divided into other two sections (see Fig. 3). As a standard, equal partitioning is recommended. However, other personalized divisions can be made if considered appropriate. Once all three parts are defined, the following criteria can be applied: (a) allocate resources for a large data collection effort to the upper section to collect as much specific data as possible; (b) carry out balanced effort regarding the middle section of the list, as general data sources can be accepted and (c) remove the lower section of the list unless data collection procedures developed for the upper and middle sections can provide necessary data without additional resources, i.e., data can be easily obtained from the EMS. Fig. 3 shows the scheme of a top-down approach with a cut-off criterion of 95% of the score.

The cut-off criterion is enriched through each O-LCA iteration based on previous experience. Many different criteria can be applied provided that they clearly serve to prioritize the collection of data on activities, processes or EAs that are expected to have the most significant environmental impacts.

2.2.5 Data collection, validation and consistency analysis

The EMS plays a relevant role by providing a good supply of information on inputs and outputs. An accounting system can serve as an alternative to a data collection process. Both sources can generate data with temporal, geographic and technological representativeness; precision; completeness; reproducibility and reliability, fulfilling the quality requirements.

All documentation used during LCI should be registered as a source, as it may be needed to validate data used. External and internal experts can carry out the validation process. The consistency analysis procedure is an additional step proposed for future iterations of O-LCA whereby once data are collected and validated, they can be compared to previous study data to detect any significant discrepancies and to provide necessary additional reviews and justifications. Matching data from different studies on the same reporting organization can highlight issues that might require further analysis as a consistency test. When significant differences are found (e.g., in the amount of energy consumption from one year to another), checking actions that could have affected this consumption may ensure the consistency of data involved.

2.3 Life Cycle Impact Assessment (LCIA) and result interpretation

Regarding LCIA, corresponding requirements are mainly the same as those established for the LCA of products (ISO 2006a, 2006b). The translation of inputs and outputs (LCI) into environmental impacts should be conducted using an existing impact assessment method, i.e., ReCiPE, CML2002, EDIP, etc. (UNEP 2015). The determination of impacts to be assessed constitutes a challenge for such organizations. Impact categories were selected in consideration of stakeholders, lessons learned from the EMAS, recommendations from the literature (Jolliet et al. 2014) and characteristics of the reporting organization analyzed. Previous case studies on environmental performance (Torregrosa et. al, 2016; Lo-Iacono-Ferreira et al. 2011, 2016a, 2016b) validate the results of a survey carried out between a representative group of stakeholders. Although the opinions of experienced practitioners are not alone sufficient for the definition of impact categories (Curran, M.A., 2017), such know-how is useful for election; therefore, members of HEIs with recognized experience in LCA were also consulted. O-LCA issues proposed include: climate change, land uses, water footprints, abiotic resource use and acidification based on a midpoint approach. These categories reflect environmental issues related to HEIs identified in previous studies and are defined in accordance with the goals and scopes defined. A midpoint method defines a category from an intervention point of view (i.e., problem oriented) while endpoint methods focus on recognizing societal value (i.e., damage oriented, such as human health) (Hauschild and Huijbregts 2015). An additional inventory level indicator for HEIs is proposed: waste generated by waste type. This indicator might help communicate impacts and spur community commitment to defined actions needed to improve the environmental performance of the reporting organization. The selection of waste types to report on can be based on the significance of such impacts. Table 2 presents the impact categories recommended for HEIs. Other indicators can be included either as midpoint or endpoint indicators. Endpoint indicators can be useful for life cycle interpretation when a broad list of midpoint indicators is also assessed. Endpoint indicators can add valuable information for interpretation. Consistency between the goals and scope of an analysis and impact category indicators must be verified.

There are no significant differences between O-LCA and product LCA in the interpretation of results either. Fig. 4 describes the five-step procedure proposed by the authors for this analysis.

Sensitivity and uncertainty analyses constitute part of the result interpretation stage. All limitations, assumptions, data quality requirements and sources must be clearly described and considered. Weak points detected during the assessment must be gathered and evaluated for further study.

Regarding communications, it is desirable to follow a systematic procedure. O-LCA results can be easily included through the EMS communication system that the EMAS requires. Different footprints could be used complementarily to communicate results as inventory-level indicators (Jolliet et al. 2014).

3 Results: application of the methodology to an EPSA case study (pilot EU)

An initial O-LCA approach based on the proposed methodology is presented. Even though the UPV EMS does not exhibit the level of performance needed to address this O-LCA, the results are presented in this section.

The complexity of an organization lies mainly in the decentralization of management and operational control. Although the EMS centralizes the monitoring of EAs identified under the EMAS, other activities and processes considered relevant for O-LCA are not yet supported with qualitative data, i.e., supplies purchases. Assessing UPV as a whole implies accessing and coordinating different areas that are not always open to this. For this reason, through our initial approach, an EU – EPSA – is used as a pilot. Limitations and barriers related to the assessment are identified and discussed in this section. The procedure is organized based on O-LCA steps.

3.1 Goals and scope

A set of definitions is shown in Table 3. Each definition is described, discussed and justified below.

The EPSA is the UPV EU chosen as a pilot for this assessment. It is defined under the EMS and it is physically located in the city of Alcoy. The EPSA consists of 3 buildings managed by staff and headed by a director. The unit also manages one vehicle, a van, for transport of goods and personnel. More details on the EPSA can be observed in Annex 2.

The director coordinates several vice-directors (appointed by the director) who are in charge of different subareas and who manage operations as illustrated in Fig. 5.

Independent of the general regulation of a public university and of the specific regulation of UPV, the EPSA has full operational control over all of its governed areas with the exception of from some facility issues: the maximum and minimum temperatures of the air conditioning system are fixed by the UPV infrastructure and maintenance office. However, air conditioning system on/off functions are still

controlled by the EPSA, giving the EU partial but significant control. The air conditioning system can be turned off or on depending on whether a room is being used or not, but the intensity cannot be freely regulated, thereby preventing extreme usage. This is an energy efficiency measure used by the highest management offices of UPV. The EPSA is a UPV school. Several departments operate through its facilities. The EU only covers activities under its operational control, e.g., the management and maintenance of facilities (electricity, maintenance, waste management, etc.) is managed by the EPSA while each department manages independent accounting on office supplies and other purchases (no control). Something similar occurs in laboratories, where supplies and additional services are bought through department or research institute accounts falling outside of the defined reporting organization. The impacts of these other activities and processes may be assessed when EUs related to them (e.g., departments) are analyzed through individual O-LCAs. All activities and processes falling within the EPSA's system boundaries are identified in the following section.

3.2 EPSA LCI

The iterative procedure proposed in the LCI section (2.2) was applied to the EPSA, with EUs chosen during the previous step. EPSA activities and processes identified by experts are shown in Fig. 6. Although the EMS Office has developed a procedure for assessing the green aspects of curricula through the analysis of study plans, the development of study plans is not managed by the EPSA but by the degree committee, a different EU. As no teaching or research activities guide the EU selected for this pilot study, no further considerations are in regards to downstream activities as suggested in the LCI methodology description section.

Flow assignments for each activity and process identified for the EPSA are included in Annex 3 as part of the prioritization procedure. Table 4 presents all inputs and outputs of the EPSA.

Basic infrastructural inputs such as electricity, water, gas, oil for mobility and natural gas for heating are considered. "Office supplies" refer to consumables—from paper and pens to toner—while "supplies" refer to consumables other than office supplies. "Technology assets" refer to electronics such as computers, interactive boards, projectors, screens, accessories, etc. "Movable assets" refer to all other movable assets other than automobiles and those considered under the technology category. Although all of these are movable, due to the relevance of their impacts, it is interesting to consider them separately. However, the amortization period should be considered for all of them when their impacts are assessed. Services refer to outsourced services, e.g., the operation of the cafeteria; see Annex 3 for a detailed description of outsourcing considerations. CO_2, SO_2, NOx, CO and HFC from fossil fuel combustion and refrigeration systems are the direct emissions considered. Waste water and different types of solid and liquid waste are also included, completing the output inventory.

EAS is the specific procedure used for the identification and classification of EAs via UPV's EMS. The assessment method is quantitative and based on algorithms for each EA. The method is defined through specific technical instructions developed by the environmental office. All EMS procedures and technical instructions of the EMS are available to stakeholders with access to the Internet, meaning that the organizational community is aware of how the system works and why. The classification objectively considers the relevance of a certain EA based on previously defined parameters such as the relationship between the consumption of a resource and the number of individuals employed under an EU.

Under Annex 3, the matrix of activities and processes vs. EA is shown with the corresponding designation for the EPSA based on a 47.5%, 47.5% and 5% division. As a result, 3 activities or processes are eligible for cut-off; 7 can be assessed through general data sources and 4 require additional efforts and resources to obtain as much specific data as possible.

Table 5 shows the results obtained along with the associations of each activity or process to impact categories recommended in the methodological proposal. Note that between the upper items, there are scope 1, 2 and 3 activities. As scope 3 activities and processes are more difficult to assess because third party collaboration is required, this may create difficulties. However, the proposed methodology is designed to highlight those subjects of study that should be assessed in detail as potential impacts that actions could have on overall environmental performance. For example, electricity consumption is classified as significant under the EMAS; however, the EPSA assume partial operational control, giving this EA a score of 2 in regards to air conditioning that requires electricity. Additionally, emissions from electricity consumption are classified by the EMAS as insignificant, and adding partial control gives this EA a score of 1. The same classification is applied for emissions from HFCs. As a result, while both aspects (direct emissions and electricity) are considered, air conditioning is given a low score on the prioritization list. Nevertheless, all items merit attention; the extended cut-off procedure is designed to be a tool that complements the knowledge and expertise of practitioners. The criterion fulfills the control approach recommended as an impact consolidation method, and ISO LCI and LCIA requirements as the most significant environmental impacts are considered. The procedure is also easy to document and understand while fulfilling documentation requirements of the standard.

As suggested in the methodology proposal section, a top-down approach is used in this pilot study. Regarding data sources, the EMS approach is used for specific data, as the aim of this study is to

determine whether an EMS verified according to the EMAS provides enough structure to complete a reliable O-LCA.
Regarding data collection measures used, emissions of GHG, SO_2, NOx and CO (climate change and acidification causes) related to fossil fuel combustion form part of the EMS based on primary data. They can easily be disaggregated for a specific EU such as the EPSA, as the EMS is already structured by EUs. Land use, water and abiotic resource use are strongly linked to infrastructure services and facilities. Waste generated based on types of waste also forms part of the EMS register. Data concerning these flows of materials are directly available from EMS registers.
Although using a robust EMAS-verified EMS generates specific data on environmental aspects such as natural resource consumption and waste generation, other resources –manufactured ones- might not form part of the EMAS system, as this restricted standard does not require their consideration. The EMS does not yet handle specific information regarding purchases.
The accounting system based on yearly budgets for supplies, office supplies and service invoices and asset registers could serve as needed information. However, the existing accounting system does not require the disclosure of details on products and services purchased required to complete an accurate assessment, e.g., when buying 10 pencils for an office, the invoice can list '10 pencils' or 'office supplies.' Purchase requests should provide more accurate information. It is unlikely that a significant number is created orally; the system is not based on enough information to address the estimation process.
Two weak points must be highlighted:

- data source assignment regarding specific data quality levels. The EMS does not include the tracking of purchases as a requirement. This lack of specific sources directly concerns an activity with higher priority: administrative procedures.
- the structure of the current EMS does not include enough information to allocate input and output flows to different activities and processes involved in assessment. This limitation affected the rest of the assessment.

LCIA for the EPSA cannot be assessed without approaching structural modifications in the EMS and/or in the accounting system in obtaining quality data related to supplies. However, some quality data are available, allowing for the partial assessment of some categories. Furthermore, the additional inventory level indicator proposed, waste generated by waste type, is fully accessible as the monitoring of waste generation is a basic function of the EPSA EMS. In this section, the partial results obtained are presented. The implications of these results are discussed in the results interpretation section of this paper.
Table 6 shows the partial results for each impact category including a symbol code that identifies the scope of each assessment. Climate change was assessed completely for scopes 1 and 2, as the EMS gathers information on all direct and indirect emissions related to infrastructure. However, scope 3 could not be assessed. Part of the information required for this indicator was obtained from the accounting system, as it was not registered under the EMS, i.e., volume of fuel consumed by the EPSA fleet. The use of land was only fully assessed under scope 1 (direct); scopes 2 and 3 present no information.
Acidification and water footprints revealed a similar outcome while abiotic resource use could not be assessed due to a lack of data. This category is directly linked to supplies, technology assets, movable assets and office supply inputs, which the EPSA EMS only monitors qualitatively; quantitative data included in the accounting system are not detailed enough.
Fig. 7 shows the additional inventory indicator and waste generation patterns by waste type defined only for scope 2. The information required for this indicator was obtained directly from the EMS.

3.3 EPSA result interpretation

Without a complete LCIA, result interpretation can be only partially discussed.
Even though the scopes of some of the impact category indicators are assessed in full, i.e., climate change for scopes 1 and 2, the EMS offers limited information on the allocation of certain flows; therefore, a more comprehensive analysis was not possible.
The additional inventory indicator defined shows that the main type of waste generated is municipal solid waste, representing almost a 60% of all waste generated. The generation of RAEEs, batteries and glass is almost insignificant according this analysis. However, the environmental impacts of at least two of these types of waste may be high. As already established, the role of this indicator is only informative.
It is interesting to note that the EMAS EMS does require the development of a communication plan. UPV creates yearly environmental reports and supports various environmental training and awareness actions in its regular activities for all of its EUs that can serve as communication platforms for O-LCA results.
Regarding the suitability of the EMAS as a framework for an O-LCA, the hypothesis of this research was founded on the experience of EMAS application at UPV and on its capacity to provide relevant and accurate environmental information for assessments and indicators. A comparison between O-LCA and EMAS requirements (Annex 1) and previous studies on LCA standards suggests that the EMAS might provide valuable information and a strong framework for addressing an EPSA O-LCA. The goal of this

study was to explore these possibilities through the development of an O-LCA methodology that considers HEI characteristics.
The methodology presented based on an EMAS EMS considers suggested definitions and procedures for addressing key O-LCA characteristics. However, the EMAS could not provide all quality data needed to carry out our pilot O-LCA of UPV EPSA EUs. Structural modifications are needed to identify information on certain relevant activities of the EPSA (e.g., environmental data related to supplies). The authors believe that the EMS is capable of managing the information needed but that new procedures are required to obtain such information. Furthermore, the compromising of personnel beyond EMS operators and third parties would be involved.

4 Conclusions and further research

In this study, the suitability of O-LCA for HEIs employing EMSs has been assessed. A methodological proposal that highlights links between the analysis and an organization's EMS is presented.
The structure of EUs defined under the EMAS proved to form a clear and useful reporting organization unit. Advice on the integration of O-LCAs of different EUs was solicited to avoid double counting mistakes. However, O-LCA development for an EU appears to be a good approach to the O-LCA of HEIs as a whole with identified barriers noted. Moreover, once the first O-LCA for the EPSA is conducted, conditions and weaknesses involved in scaling the assessment to all 211 EUs of UPV should come to light and an O-LCA of UPV as a whole might become easier to conduct as a sum of O-LCAs of EU results with special attention to the prevention of double counting mistakes. The proposed procedure should be valid for all HEIs divided into EUs with similar characteristics. Further research should be carried out in this direction.
The number of equivalent students has been recommended as a reporting flow and an upgraded prioritization procedure has been developed. The procedure considers both the quantitative relevance of EAs and EU control over related activities or processes. The methodology aims to highlight those subjects of study to be assessed in detail.
The option to freely choose consolidation methods creates enough flexibility to define a reporting organization, and this in turn allows for synergies between O-LCA and a reliable EMS when implemented. When the reporting organization is clearly defined, risks of double counting or EA omission are low, as system boundaries and limits are defined in accordance with EU structures that compose HEIs. The O-LCA approach is thus applicable to HEIs, and the EMS serves as a strong tool for defining the goals and scopes LCIs.
However, using an EMS verified under the EMAS does not ensure the availability of data required, e.g., office supply data for some EPSA flows, and thus does not ensure successful LCIA development. The LCIA has only been assessed in part with little interest to consequences of a lack of access to quality data. The inclusion of quantitative information on EMS flows is not a lost cause. Nevertheless, significant resources—both human and economic—are needed to centralize detailed information on these flows. This barrier reveals a management weak point that must be considered (particularly for the pilot organization, the EPSA): the accounting system must be updated to be able to provide more accurate and detailed information on procurements and if possible in material units (kg, kW, etc.) rather than monetary units, which add uncertainty. Another weak point pertains to the flexibility of the organizational chart used, as some activities and processes can change in terms of control approaches, e.g., processes developed through an outsourcing contract could be transferred to an internal area (e.g., cleaning services could become part of the infrastructural affairs sub-direction). In this case, clearly reporting such changes in the next iteration of the O-LCA should be sufficient for a correct interpretation of results.
Overall, both tools, the EMAS and O-LCA, are based on the same principles: performance, transparency and credibility. Although running an EMS verified according to the EMAS does not ensure the successful performance of an O-LCA, it can provide an HEI with a solid framework for easily addressing required changes as long as such a project has the support of the responsible HEI.

5 References

Braunschweig A. (2014) GHG-balances and LCA: Applying the concept of scopes in organisational LCAs. E2 Management Consulting http://www.e2mc.com Accessed 1 July 2016
Clift R, Wright L (2000) Relationships between environmental impacts and added value along the supply chain. Technol Forecast Soc 65(3):281-295. doi:10.1016/S0040-1625(99)00055-4
Cortese AD (2003) The critical role of higher education in creating a sustainable future. Planning for higher education. Retrived from http://www.aashe.org/ documents/resources/pdf/Cortese_PHE.pdf. Accessed 1 June 2016.
Curran MA (2017) Goal and Scope Definition in Life Cycle Assessment. Springer. doi: 10.1007/978—94-024-0855-3.
Disterheft A, da Silva Caeiro SSF, Ramos MR, de Miranda Azeiteiro UM (2012). Environmental Management Systems (EMS) implementation processes and practices in European Higher Education

Institutions–top-down versus participatory approaches. J Clean Prod 31:80-90. doi:10.1016/j.jclepro.2012.02.034
EC (2013) European Commission Organization Environmental Footprint Guide. European Commission - Joint Research Centre - Institute for Environment and Sustainability http://eur-lex.europa.eu/JOHtml.do?uri=OJ:L:2013:124:SOM:EN:HTML Accessed 1 June 2016.
EC (2016) European Commission Environment. Eco-Management and Audit Scheme http://ec.europa.eu/environment/emas/ Accessed 1 June 2016.
Finkbeiner M, Wiedemann M, Saur K (1998) A comprehensive approach towards product and organisation related environmental management tools. Int J Life Cycle 3(3):169-178. doi:10.1007/BF02978825
Fleischer G, Gerner K, Kunst H, Lichtenvort K, Rebitzer G (2001) A semi-quantitative method for the impact assessment of emissions within a simplified life cycle assessment. Int J Life Cycle Ass 6(3):149-156. doi:10.1007/BF02978733
GRI (2005) GRI Boundary Protocol. Global Reporting Initiative. https://www.globalreporting.org/resourcelibrary/GRI-Boundary-Protocol.pdf Accessed 1 June 2016
Hauschild MZ, Huijbregts MA (2015) Introducing Life Cycle Impact Assessment. Hauschild MZ, Huijbregts MAJ (ed) Life Cycle Impact Assessment, LCA Compendium – The Complete World of Life Cycle Assessment Springer Science+Business Media Dordrecht 2015, doi:10.1007/978-94-017-9744-3_1
Hellweg S, Milà i Canals L (2014) Emerging approaches, challenges and opportunities in life cycle assessment. Science 344(6188):1109–1113. doi:10.1126/science.1248361
Hochschorner E, Göran F (2003) Evaluation of two simplified life cycle assessment methods. Int J Life Cycle Ass 8(3):119-128 doi:10.1007/BF02978456
Huang YA, Lenzen M, Weber CL, Murray J, Matthews HS (2009) The role of input-output analysis for the screening of corporate carbon footprints. Econ Systems Res 21(3): 217–242. doi:10.1080/09535310903541348
ISO (2004). Environmental management systems -Requirements with guidance for use ISO 14001: 2004. Geneva, Switzerland: International Organization for Standardization.
ISO (2006a) ISO 14040: Environmental Management — Life Cycle Assessment — Principles and framework. Geneva, Switzerland: International Organization for Standardization.
ISO (2006b) ISO 14044: Environmental Management — Life Cycle Assessment — Requirements and Guidelines. Geneva, Switzerland: International Organization for Standardization.
ISO (2014a) ISO/TS 14072: Environmental management — Life cycle assessment — Requirements and guidelines for Organizational Life Cycle Assessment. Geneva, Switzerland: International Organization for Standardization.
ISO (2014b) ISO 14046: Water footprint — principles, requirements and guidance. Geneva, Switzerland: International Organization for Standardization.
Jolliet O, Frischknecht R, Bare J, Boulay AM, Bulle C, Fantke P, Weisbrod A (2014) Global guidance on environmental life cycle impact assessment indicators: Findings of the scoping phase. Int J Life Cycle Ass 19(4):962–967. doi:1007/s11367-014-0703
Life Cycle Initiative (2016) http://www.lifecycleinitiative.org/ Accessed 22 June 2016
Lo-Iacono-Ferreira VG, Torregrosa-López JI, Capuz-Rizo SF (2016) Use of Life Cycle Assessment methodology in the analysis of Ecological Footprint Assessment results to evaluate the environmental performance of universities. J Clean Prod 133:43-53. doi:10.1016/j.jclepro.2016.05.046
Lo-Iacono-Ferreira V, Torregrosa-López JI, Lora García J, Bastante-Ceca MJ, Capuz-Rizo SF (2011) Study of the inclusion of life cycle assessment impact categories in ecological footprint. XV International Congress of Project Engineering. ISBN: 978-84-615-4543-8
Lozano R (2006) Incorporation and institutionalization of SD into universities: breaking through barriers to change, J Clean Prod 14(9):787–796. doi:10.1016/j.jclepro.2005.12.010
Lozano R (2011) The state of sustainability reporting in universities. Int J Sust Higher Ed 12(1):67-78. doi:10.1108/14676371111098311
Manzardo A, Loss A, Mazzi A, Scipioni A, (2016) Organizational Life-Cycle Assessment (OLCA): Methodological Issues and Case Studies in the Beverage-Packaging Sector. Environmental Footprints of Packaging. Springer. doi: doi.org/10.1007/978-981-287-913-4
Martínez-Blanco J, Inaba A, Quiros A, Valdivia S, Milà-i-Canals L, Finkbeiner M (2015a) Organizational LCA: the new member of the LCA family—introducing the UNEP/SETAC Life Cycle Initiative guidance document. Int J Life Cycle Ass 20(8):1045-1047 http://doi.org/10.1007/s11367-015-0912-9
Martínez-Blanco J, Inaba A, Finkbeiner M (2015b) Halfway point in the flagship project LCA of organizations by UNEP/SETAC Life Cycle Initiative. Int J Life Cycle Ass Japan 11: 1-7.
Martínez-Blanco J, Inaba A, Finkbeiner M (2015c) Scoping organizational LCA—challenges and solutions. Int J Life Cycle Ass 20(6): 829-841.doi: 10.1007/s11367-015-0883-x
Pelletier N, Allacker K, Pant R, Manfredi S (2013) The European Commission Organisation Environmental Footprint method: comparison with other methods, and rationales for key requirements. Int J Life Cycle Ass 19(2):387–404. doi:10.1007/s11367-013-0609-x

Suh S, Lenzen M, Treloar G, Hondo H, Horvath A, Huppes G, Jolliet O, Klann U, Krewitt W, Moriguchi Y, Munksgaard J, Norris G (2004) System boundary selection in life-cycle inventories using hybrid approaches. Environ Sci Technol 38(3):657– 664. doi:10.1021/es0263745
Resta B, Gaiardelli P, Pinto R, Dotti S (2016) Enhancing environmental management in the textile sector: An Organisational-Life Cycle Assessment approach. J Clean Prod 135:620–632 doi: doi.org/10.1016/j.jclepro.2016.06.135
Taylor AP, Postlethwaite D (1996) Overall Business Impact Assessment (OBIA). In Proceedings of the 4th SETAC Case Study Symposium, Brussels, Belgium. Brussels: SETAC. 181-187
Tlapa DA, Limón J, Báez YA (2009) Quality and Environmental Management in Higher Education Institutes by Integrating ISO 9001 and ISO 14001. Form Univ 2(2):35-46 doi: /10.4067/S0718-50062009000200006
Torregrosa-López JI, Lo-Iacono-Ferreira V, Martí-Barranco C, Bellver-Navarro CG (2016) The strengths of EMAS as an environmental management system for European university campuses. Int J Environ Sust Dev15(1):89-106. doi:10.1504/IJESD.2016.073339
UNEP (2015) Guidance on Organizational Life Cycle Assessment. Life-Cycle Initiative, United Nations Environment Programme and Society for Environmental Toxicology and Chemistry, Paris, France. http://www.lifecycleinitiative.org/wp- content/uploads/2015/04/o-lca_24.4.15-web.pdf Accessed 1 June 2016
Vivancos Bono JL (2005) Propuesta Metodológica para la Simplificación del ACV en su Aplicación a los Componentes Plásticos del Automóvil en el Marco del Ecodiseño. Ed. Universidad Politécnica de Valencia.
Watkins P, Glover A (2016) Future Generations: Developing Education for Sustainability and Global Citizenship for University Education Students. In: Leal Filho W, Pace L (ed) Teaching Education for Sustainable Development at University Level, Springer International Publishing, pp67-81 doi:10.1007/978-3-319-32928-4_5
WRI and WBCSD (2011) Corporate Value Chain (Scope 3) Accounting and Reporting Standard – Supplement to the GHG Protocol Corporate Accounting and Reporting Standard. World Resources Institute and World Business Council for Sustainable Development. http://www.ghgprotocol.org/files/ghgp/public/Corporate-Value-Chain- Accounting-Reporing-Standard_041613.pdf. Accessed

Tables

Table 1 Score assignment rule for activities and processes based on EAS and CS classification.

EAS	CS	Score
S	CC	3
S	PC	2
NS	CC	2
NS	PC	1

Table 2. Impact categories recommended for HEIs

Impact category	Type of indicator
Climate change	Midpoint
Land use	Midpoint
Water footprint	Midpoint
Energy resources use	Midpoint
Abiotic resources use	Midpoint
Acidification	Midpoint
Waste generation by type	Inventory level

Table 3 Goal and scope definition.

Organization to be studied	Universitat Politècnica de València
Reporting organization	Higher Polytechnic School of Alcoy (EPSA) – UPV
Period considered	2015
Consolidation method	Operational control (see description in section 4.1.1).
Reporting flows and system boundaries	Will be described in the *Reporting flows and system boundaries* section (4.1.2).
Operations, facilities and sites of the organization considered	Will be described in the LCI analysis section (4.2)
Impact assessment methodology and types of impact	Will be described in the LCIA section (4.3).
Allocation procedures	No allocation procedures will be needed, as the product/service to be considered is unique; results do not need to be split.
Data quality requirements	Criteria such as temporal, geographical and technological representativeness, precision, completeness, reproducibility and reliability will be described for each reporting flow assessed
Limitations	Results are not designed to be used in comparative assessments created to be disclosed to the public. The results will be limited by the quality of data accessed.

Table 4 EPSE inputs and outputs

Inputs
Electricity
Water
Gasoil
Natural gas
Office supplies
Supplies
Automobiles
Technology assets
Movable assets
Services
Other supplies

Outputs
SO_2, NOx, CO, HFC, CO_2 emissions
Debris
Electric and electronic waste
Oil, fuel and hydrocarbon waste
Paper and cardboard waste
Light packaging waste
Ink and toner waste
Municipal solid waste
CD waste
Waste water

Table 5 Prioritized list of EPSE activities and processes.

				Environmental Impact Categories					Additional inventory indicator[1]
Activities or processes	Scope	∑%	Section	Climate change	Land use	Water footprint	Abiotic resource use	Acidification	Waste generation
Waste management system	2	13,3%	Upper	-	■	-	■	-	■
Administrative procedures	1	24,4%	Upper	-	■	-	■	-	-
Outsourcing: Maintenance of infrastructure	3	35,6%	Upper	-	■	■	■	■	-
Outsourcing: Cafeteria	3	46,7%	Upper	-	■	■	■	■	-
Outsourcing: Electric maintenance	3	54,8%	Middle	-	■		■	■	-
Outsourcing: Construction services	3	63,0%	Middle	-	■	■	■	■	-
Outsourcing: Cleaning services	3	69,6%	Middle	-	■	■	■	■	-
Lighting and lift system	2	75,6%	Middle	■	■	-	■	-	-
Mobility with UPV fleet	1	80,7%	Middle	■	■	-	■	■	-
Sanitary system	2	85,2%	Middle	-	■	■	■	-	-
Capital equipment procurement	3	89,6%	Middle	-	■	-	■	■	-
Outsourcing: Security system	3	93,3%	Middle	-	■	-	■	■	-
Air conditioning system	2	96,3%	Lower	■	■	-	■	-	-
Outsourcing: others	3	98,5%	Lower	-	■	■	■	■	-
Heating system	2	100,0%	Lower	■	■	-	■	■	-

The complete prioritized procedure for EPSA activities and processes is detailed in Annex 3. included; - not included. [1]Note that the additional inventory indicator is only defined for scope 2.

Table 6. Partial LCIA results for the EPSA

Impact Categories	**value**	**unit**	**Scope 1**	**Scope 2**	**Scope 3**
Climate change	677.90	t CO_2e	■	■	□
Land use	2.87	ha	■	-	-
Water footprint	6661	m3	■	-	-
Abiotic resource use	-	-	-	-	-
Acidification	0.17	t SO_2e	■	-	-

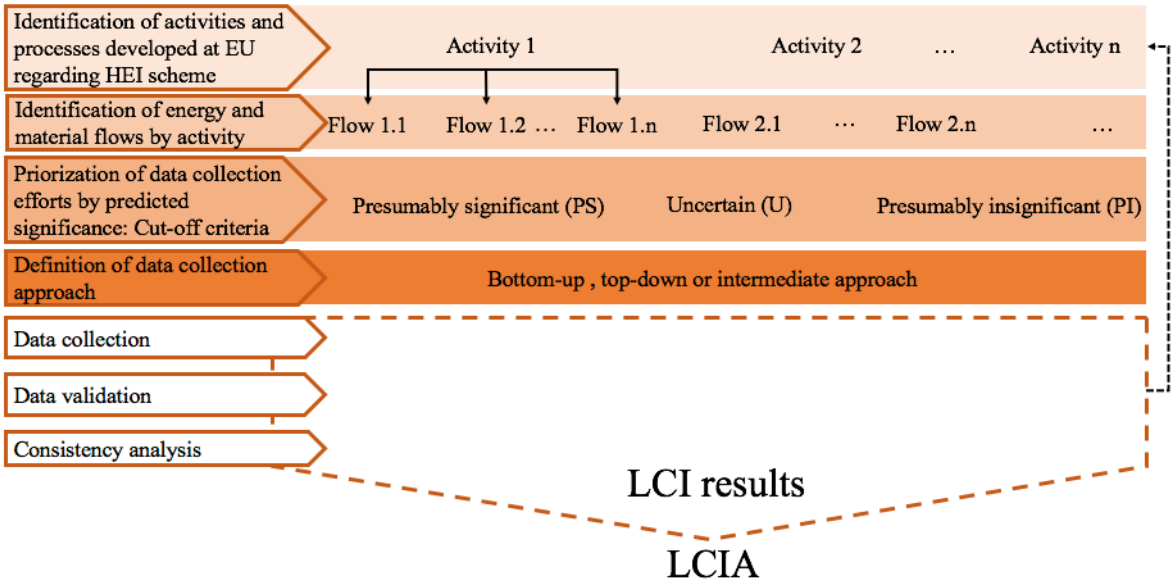

Fig. 1 Procedure for analyzing EU flows. Developed by the authors.

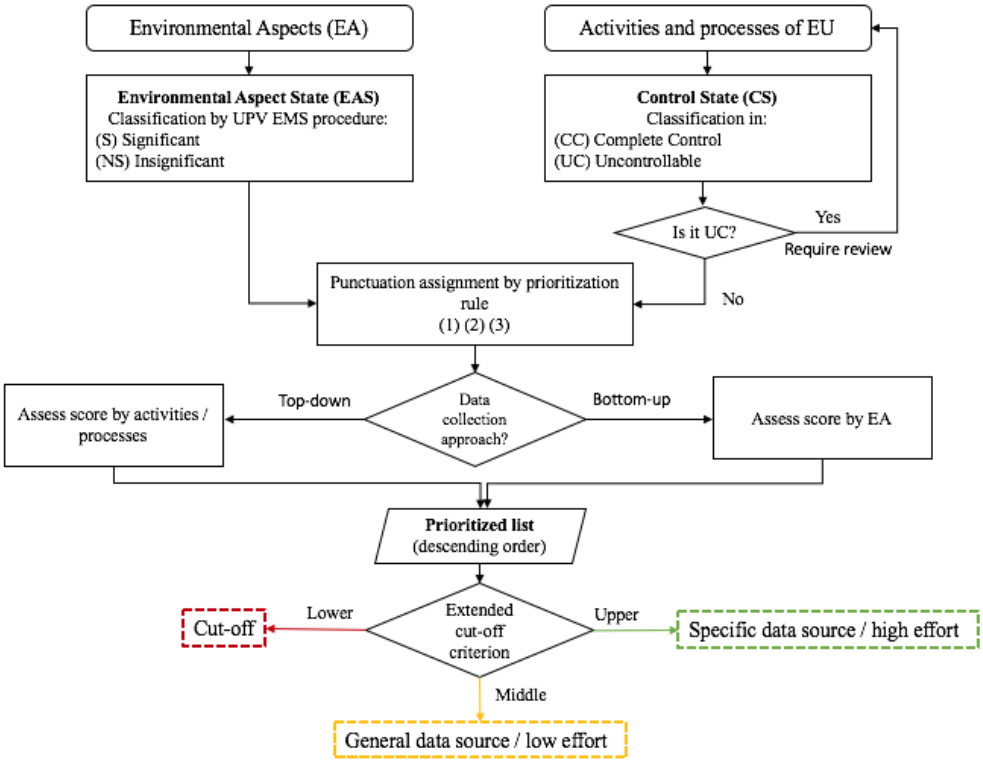

Fig. 2 Prioritization of data collection efforts and cut-off procedure. Developed by the authors.

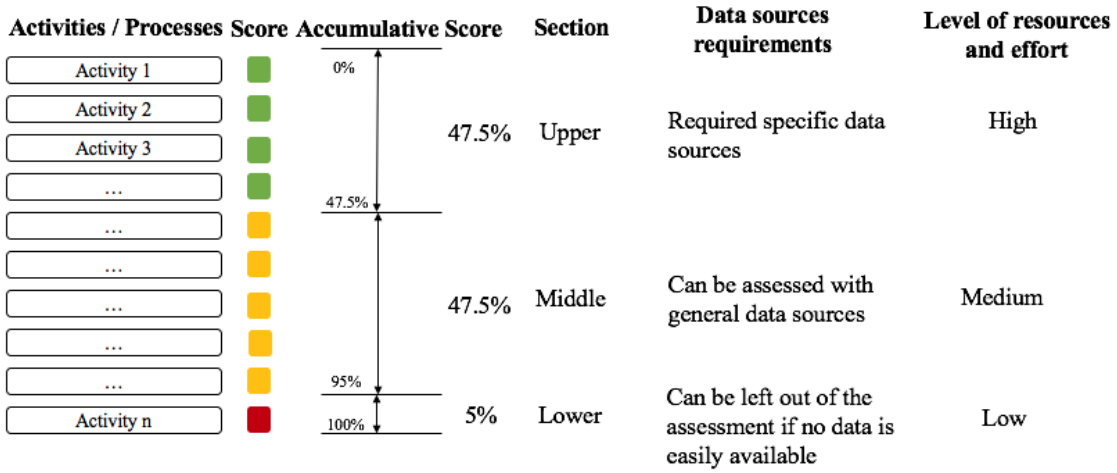

Fig. 3 Top-down prioritization approach with 95% cut-off criterion scheme.

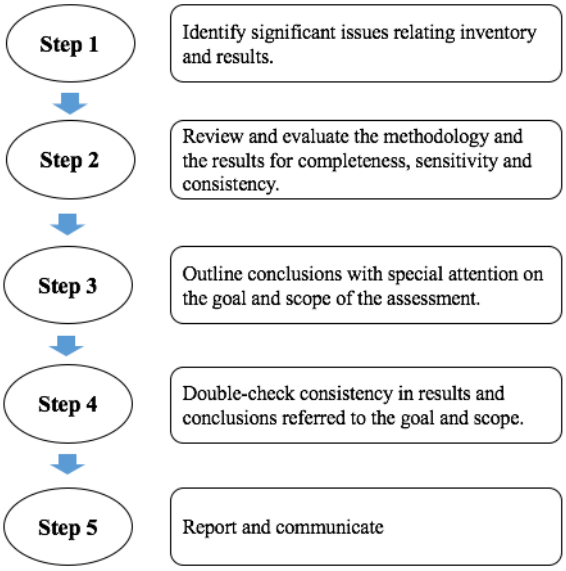

Fig. 4 Result interpretation procedure recommended for HEIs. Prepared by the authors.

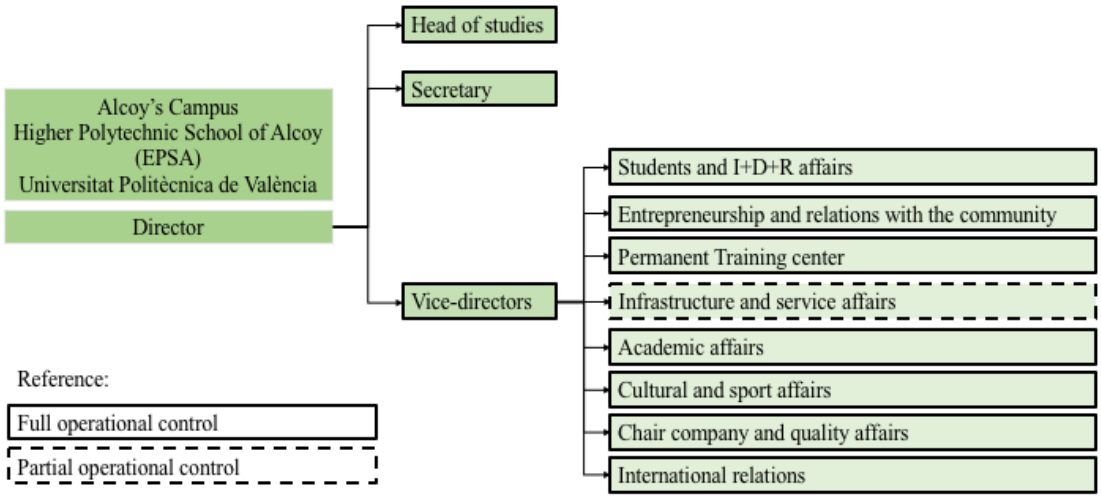

Fig. 5 Operational control scheme of the EPSA.

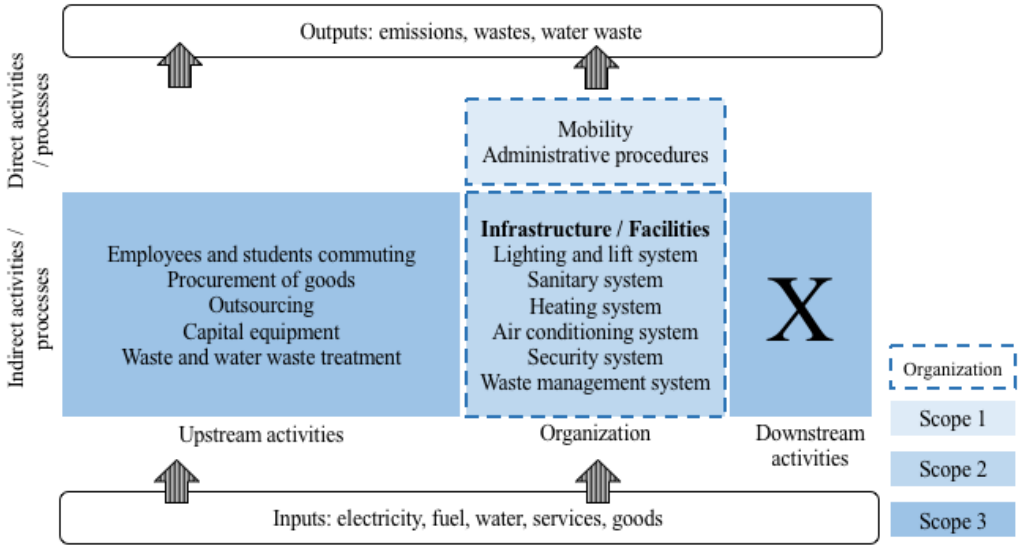

Fig. 6 Activities and processes of the EPSA. Developed by the authors based on UNEP (2015).

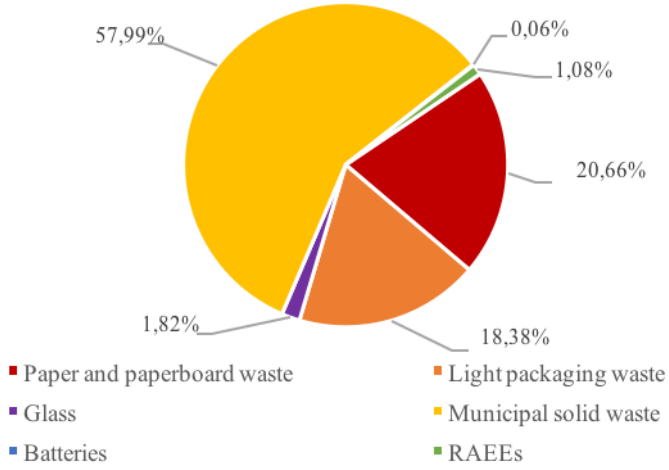

Fig. 7 Inventory indicator for the EPSA: Waste generation by waste type. Percentage in weight for each type of waste generated.

Annex 1 Comparison between ISO 14072:2014 and EMAS requirements

In this Annex, table 7 presents a comparison between the most significant requirements of ISO 14072:2014 and the EMAS. The table is organized based on ISO structure represented in the left-hand columns.
Note that EMAS requirements follow but are not limited to ISO 14001:2004. Every organization with EMAS verification complies with ISO 14001:2004 requirements and must address a number of additional issues. Further details can be found in Annex 1 of EMAS regulation 1221/2009 (EC 2009). As both tools (O-LCA and EMAS) have a direct or indirect link to ISO 14000 standards, it is foreseeable that they have certain elements in common.
A color code is used to identify different types of information in the EMAS columns. Regarding ISO 14072:2014 column, all highlights was extracted from requirements or the official guide.

- White background, normal: text extracted from requirements and valid for ISO 14001:2004 and the EMAS.
- White background, bold: text extracted from requirements only applicable under the EMAS.
- Grey background, bold: not explicitly defined concepts but concepts implicit in EMAS operations.
- Grey background, normal: not explicitly defined concepts but concepts that might be partially implicit in EMAS operations. When this is the case, this is reported.

Table 7 Comparison between ISO 14072:2014 and the EMAS

Selected items of the ISO structure			**ISO 14072:2014 highlights from requirements**	**EMAS-related characteristics**
Goal and scope definition	Goal		The goals of the study shall be unambiguously stated.	The organization shall establish, document, implement and maintain an EMS. An environmental policy is defined in accordance with the nature, scale and environmental impacts of organization activities, products and services. The environmental policy provides a framework for setting and reviewing environmental objectives and targets.
	Scope	Products, services, operations and Reporting Unit	The products, services and operations of the organization and the reporting unit shall be clearly specified. The reporting unit shall be consistent with the goals and scope of the study.	
		System boundary	The system boundary defines processes to be considered in the assessment. Cut-off criteria shall be clearly defined.	The organization shall carry out an initial environmental review to identify and evaluate its EAs and to identify applicable legal requirements that are environmentally related. The organization shall establish, implement and maintain documented environmental objectives and targets.
		LCIA methodology and types of impacts	The election of impact categories, indicators and characterization models shall be consistent with the goals and scope of the study.	The organization shall establish, implement and maintain a procedure for identifying the EAs of its activities, products and services within the scope of the EMS. Additionally, it must determine those aspects that have or that can have significant environmental impacts. When assessing the significance if EAs, the organization shall consider issues such as the potential to cause environmental harm; the fragility of the local, regional or global environment; the size, number, frequency and reversibility of an aspect or impact; the existence and requirement of relevant environmental legislation; and degrees of importance to organization stakeholders and employees.
		Types of sources and data	Data can be obtained by measuring the production point associated with the process studied or with other sources. Data can also be calculated.	Management shall ensure the availability of resources needed to establish, implement, maintain and improve the EMS. Resources include human resources and specialized skills, organizational infrastructure, technology and financial resources.
		Data quality requirements	Quality requirements shall be clearly defined.	There is no reference to data quality requirements in EMAS regulations. However, an unambiguous procedure must be applied for the assessment of each EA. These procedures detail how data are to be obtained and managed based on information on their quality.
		Comparison between systems	A statement that the results are not intended to be used in comparative assertions to be disclosed to the public is required.	The EMAS does not specify comparative purposes between organizations. However, indicators must allow for comparisons across sector, national or regional benchmarks.
		Critical review considerations	When an OLCA must be communicated to third party, a critical review should be performed.	Internal audits shall be conducted at planned intervals. External audits shall be conducted every three years for renovation purposes.
Life Cycle Inventory (LCI)	Data collection		Data shall be collected for each individual process included within the system boundaries. Data shall be used to quantify inputs and outputs of each process.	All required resources, including humans and technology, shall be ensured by management personnel. The data collection process should not pose an issue if required resources are available for a specific purpose.
	Calculating data	Validation of data	Data validation must be carried out to ensure that quality requirements are met.	Organizations must be able to demonstrate that significant EAs associated with their procurement procedures have been identified and that significant environmental impacts associated with these aspects are addressed within EMSs. Environmental verifiers shall verify, among other things, the reliability, credibility and correctness of data and information in the environmental statement; related updates and any other environmental information to be validated.
		Relating data to unit processes and reporting units	Assets such as buildings and equipment are used over a time period that may be different from the time period fixed by the LCA. LCI calculation methods for these assets should take into account the time period over which they are used and should be clearly justified and documented.	
		Refining system boundaries	System boundaries shall be reviewed in accordance with defined cut-off criteria.	
	Allocation		Inputs and outputs shall be allocated to different products, services and operations based on clearly stated procedure that shall be documented.	**Although this is not specified as a requirement, it constitutes an essential part of the overall functioning of the system; data must be allocated to assess the significance of each EA.**
Life Cycle Impact Assessment (LCIA)	Mandatory elements of LCIA	Selection of impact categories, category indicators and characterization models	The selection of impact categories shall reflect a comprehensive set of environmental issues related to the organization being studied while taking the goals and scope into consideration.	The EMAS does not specify impact categories; it considers the potential to cause environmental harm based on the fragility of the local, regional and global environment. However, it does require the definition of environmental performance indicators (at least one for each EA identified and related to key environmental areas such as energy efficiency, material efficiency, water, waste, biodiversity and emissions).
		Assignment of LCI results to the selected	The procedure used to assess each impact category shall be identified and documented.	

Selected items of the ISO structure			ISO 14072:2014 highlights from requirements	EMAS-related characteristics
		impact categories		
		Calculation of category indicator results and resulting data after characterization	Inputs and outputs shall be represented after result characterization (e.g., via a direct compilation of the results of indicators by category).	**The EMAS requires the definition of indicators and their assessment for significance analysis and environmental review.**
	Optional elements of LCIA	Normalization	This can be applied to verify consistency, to communicate information and to prepare additional procedures.	**The EMAS requires the normalization of environmental performance indicators:** **- For the production sector, state the total gross value-added, annual turnover or number of employees (the last two options can only be used for small organizations).** **- For the non-production sector, state the number of employees.**
Life cycle interpretation	Identification of significant issues		Results shall be interpreted according to the goals and scope of the study. The interpretation shall include an identification of significant inputs, outputs and methodological choices.	**The environmental performance of the organization against its objectives and targets shall be evaluated as part of the management review process.**
		Completeness and sensitivity check	A completeness and sensitivity check must be conducted to ensure that all information and data needed for the interpretation of results are available. When any relevant information is missing, the previous stages must be reviewed and goals and scopes must be adjusted.	Internal audits of the EMS shall be conducted at planned intervals to determine whether the EMS conforms to planned arrangements and has been properly implemented and maintained. The audit shall also provide information on audit results to management personnel. Upper management teams shall review the organization's EMS at planned intervals to ensure its continual suitability, adequacy and effectiveness.
		Consistency check	Issues regarding possible data quality gaps, regional and/or temporal differences, etc., shall be clearly described.	The management review shall include results of internal audits, communications from external interested parties including complaints, the environmental performance of the organization, the extent to which objectives and targets have been met, etc. As an output, managers shall present a report citing decisions and actions related to possible changes in environmental policies, objectives, targets and other elements of the EMS.
	Conclusions, limitations and recommendations		Conclusions shall be based on the study results. Limitations shall be clearly described and recommendations shall be made based on both outcomes.	**The organization shall commit itself to the continual improvement of its environmental performance. In doing so, the organization may base its actions on local, regional and national environmental programs.**
Reporting			The report shall unambiguously describe system boundaries, processes, data including data quality requirements, and impact categories and category indicators selected.	**Organizations shall be able to maintain an open dialogue with the public and with other interested parties including local communities and customers with regards to the environmental impact of their activities, products and services to identify the public's and other interested parties' concerns. Openness, transparency and the periodic provision of environmental information are key factors associated with building trust with interested parties. The EMAS allows organizations to target relevant information to specific audiences while ensuring that all information is available to those who need it.**

Annex 2. EPSA and UPV information for 2015

Organization: Universitat Politècnica de València.
CIF: Q4618002B
NACE: 85.42 (tertiary education)
Total staff members: 7,887
Total students: 38,486
Total building surface: 694,169 m^2
Total landscaped area: 128,517 m^2
Number of environmental units: 211 (see Table 8 for more information).

Environmental Unit assessed: Escuela Politécnica Superior de Alcoy (EPSA)
Address: Plaza Ferrándiz y Carbonell 1. (03801 Alcoy) Spain
Staff members: 300
Students: 2,494
Building surface: 28,717 m^2
Landscaped area: 1,270 m^2

Table 8. Environmental units of UPV

Type	**Units**
Faculties	14
Departments	44
Research institutes	35
Services	91
Third party facilities	27
Total	**211**

Data source: Environmental Management System Report 2015. Internal use only. Available under requirement Code: UPV.MA-INF.RSGA.2015-UPV-01.

Annex 3 Prioritization procedure for the EPSA LCI analysis

For a better analysis, the LCI is divided into 2 matrixes: significant (Table 9) and insignificant (Table 10) environmental aspects. Table 11 presents results from both tables. Scores are assigned following the proposed score assignment rule (Table 1 of the main body of the article).

Table 9 Matrix of activities and processes for significant (S) EAs

Scope		1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	
Reporting organization: EPSA - UPV	Activities and processes	Administrative procedures	Mobility within UPV fleet	Lighting and lift system	Sanitary system	Heating system	Air conditioning system	Waste management system	Capital equipment procurement	Outsourcing: Cleaning services	Outsourcing: Maintenance of infrastructure	Outsourcing: Electric maintenance	Outsourcing: Security system	Outsourcing: Construction services	Outsourcing: Cafeteria	Outsourcing: others	**Score by EA**
Environmental Aspects (EA)	**CS / EAS**	**CC**	**PC**	**CC**	**PC**	**PC**	**PC**	**CC**	**CC**	**PC**	**PC**	**PC**	**PC**	**PC**	**PC**	PC	
Water consumption	**S**				3						2			2	2		**9**
Electricity consumption	**S**			3			2			2	2	2	2	2	2		**17**
Battery waste generation	**S**			3													**3**
CD waste generation	**S**	3															**3**
Electronic waste generation	**S**										2	2					**4**
Paper and cardboard waste generation	**S**	3						3				2			2		**10**
Office supply consumption (1)	**S**	3						3									**6**
Supply consumption (1)	**S**							3									**3**
Automobile procurement (1)	**S**		2														**2**
Movable asset consumption (1)	**S**								3								**3**
Technology asset consumption (1)	**S**								3								**3**
Environmental behavior of external companies (2)	S									2	2	2	2	2	2	2	**14**
Emission generation due to gas/oil consumption (3)	S		2														**2**
Waste water generation	S				3					2	2			2	2		**11**
Automobile waste generation	S		2														**2**
Score for activities and processes		**9**	**6**	**6**	**6**	**0**	**2**	**9**	**6**	**6**	**10**	**8**	**4**	**8**	**10**	**2**	**92**

(1) The EMS assessed as a unified EA for consumption. It is disaggregated for better analysis according to the scope of this work.
(2) Refers to the 'services' input related to outsourcing.

(3) The EMS assesses a unified EA for emissions due to energy. It is disaggregated for better analysis according to the scope of this work.

Table 10 Matrix of activities and processes for insignificant (NS) EAs

Scope	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	
Reporting organization: EPSA - UPV	Activities and processes	Administrative procedures	Mobility within UPV fleet	Lighting and lift system	Sanitary system	Heating system	Air conditioning system	Waste management system	Capital equipment procurement	Outsourcing: Cleaning services	Outsourcing: Maintenance of infrastructure	Outsourcing: Electric maintenance	Outsourcing: Security system	Outsourcing: Construction services	Outsourcing: Cafeteria	**Score by EA**
Environmental Aspects (EA)	**CS / EAS**	**CC**	**PC**	**CC**	**PC**	**PC**	**PC**	**CC**	**CC**	**PC**	**PC**	**PC**	**PC**	**PC**	**PC**	**10**
Emissions due to electricity consumption (3)	NS			2			1			1	1	1	1	1	1	**2**
Debris generation	**NS**										1			1		**1**
Emissions due to air conditioning, HFC	NS						1									**2**
Fossil fuel consumption: natural gas (4)	**NS**					1									1	**1**
Fossil fuel consumption: gas/oil (4)	**NS**		1													**2**
Emissions due to natural gas consumption (3)	**NS**					1									1	**1**
Oil, fuel and hydrocarbon waste generation	**NS**										1					**9**
Light packaging waste generation	**NS**	2						3		1	1	1			1	**10**
Municipal solid waste generation	**NS**	2						3		1	1	1		1	1	**5**
Ink and tonner waste generation	**NS**	2						3								43
Score for activities and processes		**6**	**1**	**2**	**0**	**2**	**2**	**9**	**0**	**3**	**5**	**3**	**1**	**3**	**5**	**1**

(3) The EMS is assessed as a unified EA for emissions due to energy. It is disaggregated for better analysis according to the scope of this work.
(4) The EMS assessed as a unified EA for fossil fuel consumption. It is disaggregated for better analysis according to the scope of this work.

Table 11 presents scores for activities and processes that are significant (S) and insignificant (NS) EAs.

Table 11 Summary matrix of activities and processes for significant (S) and insignificant (NS) EAs.

Activities and processes	Administrative procedures	Mobility within UPV fleet	Lighting and lift system	Sanitary system	Heating system	Air conditioning system	Waste management system	Capital equipment procurement	Outsourcing: Cleaning services	Outsourcing: Maintenance of infrastructure	Outsourcing: Electric maintenance	Outsourcing: Security system	Outsourcing: Construction services	Outsourcing: Cafeteria	Outsourcing: Other	**Score by EA**
CS	**CC**	**PC**	**CC**	**PC**	**PC**	**PC**	**CC**	**CC**	**PC**	**PC**	**PC**	**PC**	**PC**	**PC**	**PC**	
Significant EA	9	6	6	6	0	2	9	6	6	10	8	4	8	10	2	**92**
Insignificant EA	6	1	2	0	2	2	9	0	3	5	3	1	3	5	1	**43**
Total score for activities and processes	**15**	**7**	**8**	**6**	**2**	**4**	**18**	**6**	**9**	**15**	**11**	**5**	**11**	**15**	**3**	**135**