WHOLE-BUILDING LCA ACCORDING WITH LEED V.4[1]

GOMES, V., University of Campinas, email: vangomes@fec.unicamp.br; SAADE, M.R.M.S., University of Campinas, email: marcellarms@hotmail.com; SILVA, M.G., Federal University of Espirito Santo, email: margomes.silva@gmail.com; PULGROSSI, L., University of Campinas, email: lizpulgrossi@yahoo.com.br

ABSTRACT

The LEED v4 Building Life-cycle Impact Reduction credit requires improved life cycle impacts compared to a baseline building. The baseline and proposed buildings must be functionally equivalent, i.e.: have comparable orientation and location, size, function and service life (>60 years) to fully account for maintenance and replacement – but the proposed building must show improved energy performance. The life cycle assessment (LCA) scope is a cradle-to-grave assessment of the building's structure and enclosure, following EN 15804:2013 system boundaries definition to encompass product, construction, use (except for energy and water), and end-of-life stages. Life cycle impacts must be calculated for six categories. A minimum 10% reduction relatively to the baseline must be demonstrated for global warming potential and other two impact categories, whilst no environmental impact category may increase by more than 5%. If all six impact categories are reduced by 10%, an extra point is awarded as Innovation credit. Typical cut-off criteria found in published whole-building LCAs is 5% of total mass and energy. Though LEED V4 tries to find the right balance between simplification whilst yielding meaningful LCA results, it applies a much larger cut-off rule. This paper explores the implications of such approach, through a Brazilian case study.

***Keywords**: LCA. Whole-building. LEED. Cut-off rules.*

1 INTRODUCTION

Life cycle assessment (LCA)'s data intensity at product level is already well known. Addressing whole-buildings adds complexity, and practitioners seek to balance simplification whilst yielding meaningful results to enable assessments also at building level. Nonetheless, interest in whole-building LCA (WBLCA) rapidly growing worldwide.

The robust European regulation framework developed by CEN TC 350 for the construction sector guides global practice. *Standards EN 15804 (CEN, 2013) and EN 15978 (CEN, 2011)* are quickly becoming standard. The transnational European *EeB Guide Project* (EeB Project, 2012) developed guidelines for using Standards EN 15804/15978. Major European building certification schemes such as DGNB and HQE incorporated the EN 15804/15978 provisions. Designers and LCA practitioners in other regions are gradually using it as well, while local standards and protocols for standardized and transparent reporting of environmental performance of buildings are still developing.

The EeB Project (2012) acknowledges that, for WBLCA, (1) it is important to ease the process, as it is a time-consuming task to account of possibly hundreds of building products in the overall LCA; and (2) some building

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products or technical equipment may not have LCA or EPD data in some countries. In this sense, the so-called cut-off rules become helpful, since they enable LCAs to be carried out without integrally modelling the product system (EeB Project, 2012). The cut-off criteria refer to the omission of non-relevant life cycle stages, activity types, specific processes and products and elementary flows from the system model (EC JRC-IES, 2010).

Cut-off rules are expressed as a percentage of impacts that have been approximated to be excluded via the cut-off. In an apparent paradox, one must know the final result of the LCA to be able to know which parts of it (i.e. processes, elementary flows etc) can be left out (EC JRC-IES, 2010). In practice, the total inventory is always unknown, but must be extrapolated from measured or calculated data.

Common cut-off criteria typically refer to mass and energy. If a study is interested in assessing e.g. (eco)toxicity indicators and comprises raw materials with low energy or mass input while having a high toxicity effect, they should always be taken into account in the life cycle inventory (EeB Project, 2012).

1.1 WBLCA practiced worldwide

Standards EN 15804/15978 admit that materials and processes can be omitted whenever the process contributes with less than 1% of total mass OR renewable or non-renewable primary energy, and all excluded materials and processes do not exceed 5% of total energy use AND mass.

The EeB Project (2012) offers specific guidance on cut-off rules for WBLCA. For complete LCAs, the ILCD Handbook provisions (EC JRC-IES, 2010) define the cut-off rules to be followed. If ILCD Handbook provisions are not achievable in practice, then the EN 15804/EN 15978 cut-off rules may be used, but the study would configure a screening or a simplified assessment (EeB Project, 2012). In that case, the practitioner should refer to a list of mandatory building products and technical equipment to include in the assessment. Items not listed remained as 'optional building products', due to potentially missing data at the time. Default values should be used whenever available at the European level, even if not very representative of a specific product, to limit the cut-off rules (validation step), while easing the completion of the study by practitioners (EeB Project, 2012).

1.2 LEED v.4 approach

The LEED v.4 'Building Life-cycle Impact Reduction' credit requires improvement relatively to a baseline building. Life cycle impacts are calculated for:

- global warming potential, GWP, in kg CO_{2e};
- depletion of the stratospheric ozone layer, in kg CFC-11;
- acidification of land and water sources, in moles H+ or kg SO_2;

- eutrophication, in kg nitrogen or kg phosphate;
- formation of tropospheric ozone, in kg NO_x, kg O_{3e}, or kg ethene; and
- depletion of nonrenewable energy resources, in MJ.

The scope should be a cradle-to-grave assessment following EN 15804:2013's system boundaries definition to encompass A1–A4 (product stage and construction process), B1–B5 (use stage) and C1–C4 (end-of-life stage). Only building structure and enclosure are assessed.

The baseline and proposed buildings must be functionally equivalent, i.e.: have comparable function; orientation and location; size; operating energy performance (compliant with Energy and Atmosphere (EA) Minimum Energy Performance Prerequisite); and service life ($\geq$ 60 years), to fully account for maintenance and replacement. The proposed building must achieve $\geq$ 5% higher energy performance than the baseline defined by ASHRAE 90.1:2010 used in the EA category. Then, LCA results must demonstrate a minimum 10% reduction - relatively to the baseline design - in the values of GWP and other two impact categories of free choice, whilst not increasing the values of the remaining environmental impact indicators by more than 5%. If the values of all six impact categories are reduced by 10%, an extra point is awarded through the 'Innovation' credit (USGBC, 2013; USGBC 2017).

Life cycle-based studies have consistently shown that envelope and structural frames are major contributors to the environmental loads of a building, and respond for 40 - 60% of overall impacts (Dobbelsteen et al., 2007). Therefore it seems reasonable to assume that, by covering the structural frame and envelope, a representative portion of all materials would be included in the assessed system product. Still, that 60-40% exclusion falls well short to meet the 5% cut-off rule admitted by EN 15978. Furthermore, products - such as floor coverings and paints - are likely to overcome the structural components' environmental impacts for specific categories. This paper explores the implications of such approach, through a Brazilian case study

2. OBJECTIVE

Our objective is to estimate how much impact is neglected by LEED, by contrasting results obtained for a case studied under two scope scenarios - 'best-of-knowledge' complete WBLCA and the simplified LEED v.4 approach – and illustrated by selected impact categories.

3. METHOD

Our case study is a 1,005.21 m^2 gross floor area living lab designed to achieve, at least, the net zero energy status and be high level-certifiable by LEED v2009. Seven strategies using Energy Plus software v. 6.0.0.023 and the EPW weather file for Campinas – SP were previously simulated to achieve a 27,32%-reduction in energy consumption and cost relatively to the baseline. This result yielded prerequisite compliance plus other six points under credit EAc1, and

would be more than enough to comply with the 5% reduction against the Standard 90.1:2010 (ASHRAE, 2010) baseline required for pursuing LCA credits in LEED v.4.

The 'best-of-knowledge' complete WBLCA' was modelled following ISO 14044 (ISO, 2006), and ILCD and EN 15804/EN 15978 provisions to configure a cradle to grave LCA with options, whereas considering national peculiarities regarding transport, wastage and replacement factors. For the simplified LEED v.4 approach, only the building's structure and enclosure were considered (Table 1).

Table 1 - Summary of methodological choices and definitions

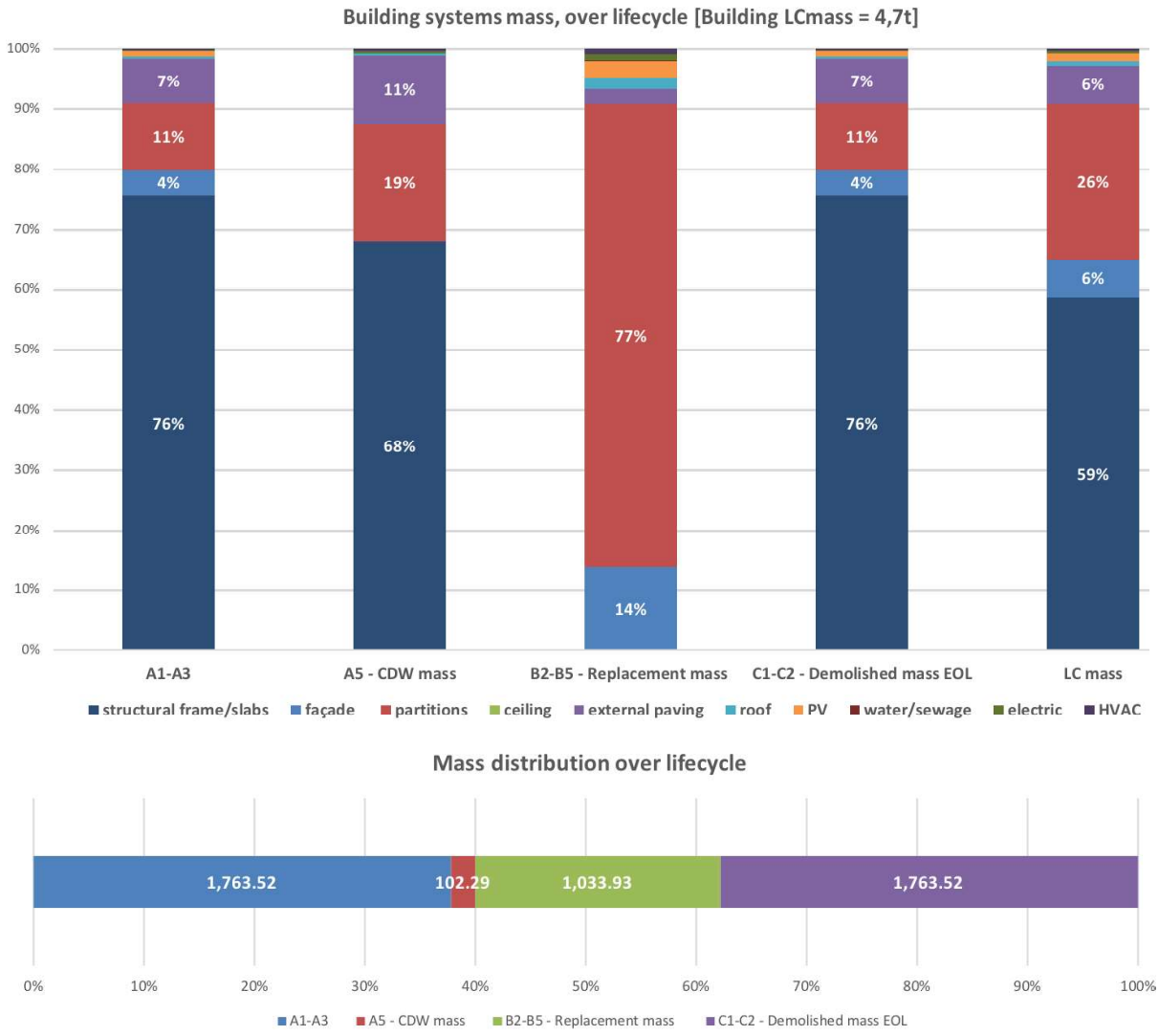
Scope	Cradle to grave (A1-5, B1-5, C1-2)
Reference study period	60 years
Operational energy simulation	Energy Plus v. 6.0.0.023
Functional unit	The whole building
Inventory data	Ecoinvent 2.2 was the most used and preferred database, but other databases were necessary for materials absent in it.
Impact assessment methods	CML 2001 (for GWP) and Cumulative Energy Demand (for CEDr, CEDnr and CED total)
Indicators	GWP, CEDr, CEDnr, CEDtotal

The impact categories selected for assessment are climate change (GWP), mandatory for LEED v.4, and depletion of nonrenewable energy resources (PENRT), expressed as non-renewable cumulative primary energy demand (CEDnren), mandatory for the EeBGuide Project. PERT (CEDren) and PET (CEDtotal) are also presented for reference purposes, as suggested by the EeB Project (2012).

4. RESULTS AND DISCUSSION

LEED v.4. LCA scope coverage is expressive (68- 80%) for all life cycle stages but the replacement modules B2-B5 (16%). Given that the structural elements set the building's reference service life, in the case studied replacement is dominated by substituting partitions (78% of replaced mass), but only minor intervention in the façades and roof (respectively 14% and 2% of replaced mass) would be captured (Figure 1). Replacement contribution to the life cycle mass will determine the magnitude of impacts left out, which would be more critical when assessing multi-tenant buildings with high churn rate, than e.g. residential buildings.

Figure 1 - Contributors to life cycle mass

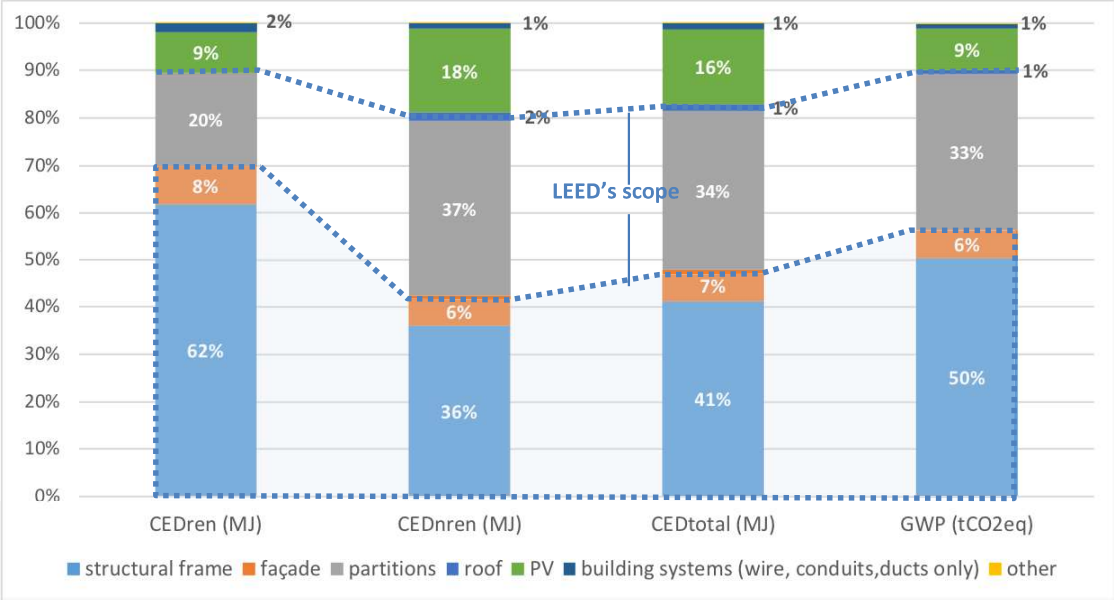


Source: The authors

Contrastingly, just around half (42% of CEDnren and 56% of GWP) of the case study's impacts at product stage (modules A1-A3) would be accounted for (Figure 2).

LEED covers impacts tracked in most LCA studies. Analyzed categories match EN 15978's predetermined impact category indicators of LCIA using characterization factors according to EN 15804. Still, some categories excluded are among the most relevant ones in regard to building materials (LASVAUX et al, 2016). Once a bill of materials is available for structure and enclosure systems, it would probably include other subsystems. Setting inventories aside, running an LCA for other relevant impact categories would demand little additional effort, but design and construction companies should adjust the content and format of the practiced bill of materials to facilitate LCAs, at development stages earlier than currently practiced to boots benefits from the study.

Figure 2 – Contribution analysis in the product stage



Source: The authors

5. CONCLUSIONS

LEED V4 tries to find the right balance between simplification whilst yielding meaningful results. However, its approach uses a simplified LCA scope, in terms of content (impact categories and lifecycle stages) and accuracy. LEED v.4 does not specify software or database to run the assessments either. In practice, that means that international data can used and could raise accuracy concerns. We did not explored this topic here, since our focus remained on assessment coverage. Some of the authors generated the first Brazilian datasets for building materials (clinker, cement, and concrete e mineral admixtures) for Ecoinvent in 2018, which will also be shared with the SICV national database. Until a massive inventory effort is carried out nationally, secondary data for all other building products will continue to be mostly adapted from international sources.

Concerning the environmental categories, LEED covers impacts tracked in most LCA studies, but some categories excluded are among the most relevant ones in regard to building materials. It would be useful to increase the optional categories to include them. The lifecycle stages encompassed are aligned with the rating system rationale, which has specific sections for operational performance. By focusing on structure and envelope, LEED's approach tries to make it applicable to most of the potentially certifiable buildings. This is expected to boost LCA use in the construction sector, but at cut-off rules far beyond those recommended internationally for WBLCA. Our dilemma is to decide which way is best to go.

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