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Ana Carolina Badalotti Passuello

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Vinícius Gonçalves Maciel

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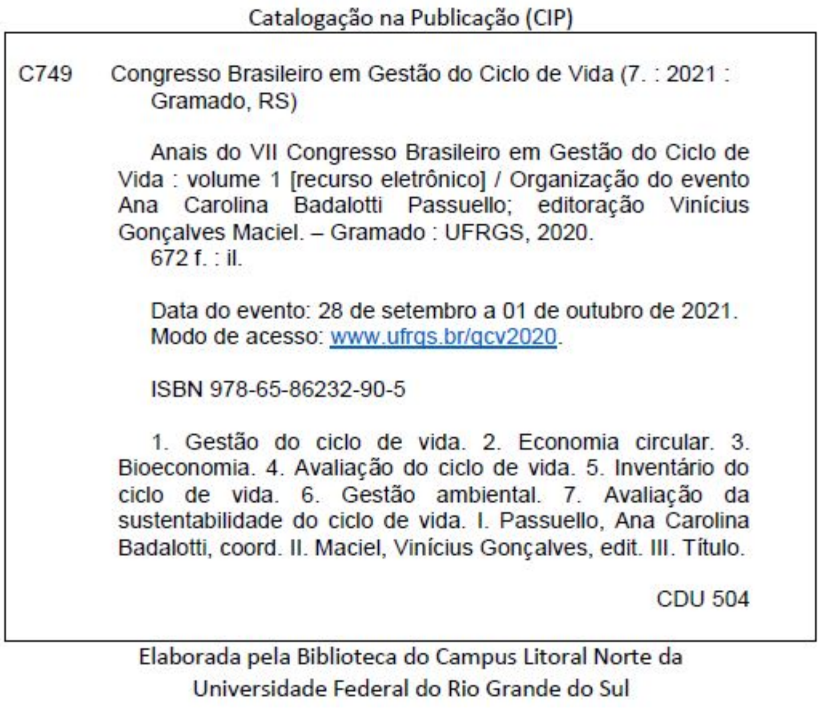

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Einstein's insanity concept revisited: why different results for the same whole building LCA are acceptable?

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Abstract

Whole building LCA involves not only a large amount of data, but also making a series of assumptions over production, construction, use, and end of life modeling. Within the IEA EBC Annex 72, assessments were carried out for reference buildings, using the same material and energy demand but applying the existing national/regional LCA approaches and databases as used in the different participant countries. In this paper, the Annex 72's challenge is replicated at the Brazilian scale: two teams were assigned with the same assessment task, in a context marked by the lack of a nationally established assessment method or database. For the case studied, a research partner established a BIM model and quantified the number of building elements, construction materials required and operational energy demand. As the main overall contextual discrepancy sources highlighted by the Annex 72 study would be the same for both teams, this investigation focused on modeling divergences, the influence of tools and cutoff rules used, and individual troubleshooting conducts. While the product stage impacts are similar - since inventories were mostly extracted and/or adapted from the omnipresent Ecoinvent database - differences are observed whenever assumptions are made along the overall modeling (e.g. cutoff rules defining modules and systems included and materials adapted to Brazilian conditions) and according with each team's strategy and specific approaches for best adherence to regional practice. Operation result variations stem from service life adopted for each building component/element, whilst different assumptions on recycling shares, waste processing, and final disposal scenarios, as well as end of life discrepancies induced by limitations of one of the modeling tools used.

Keywords: *Life cycle assessment, whole building LCA, modeling choices, LCA assumptions.*

Introduction

In his famous statement, Albert Einstein, defined insanity as *'…doing the same thing over and over again and expecting different results'*. But how insane would it be to do things somewhat differently while expecting similar results? Though LCA analysts' affinity with high-complexity assessments would pretty much label them as insane, the numerous normative choices made throughout an assessment can indeed lead to different results, even though the different assessments are all presumably correct. This paper offers a provocative invitation for reflecting about the 'acceptable range' that results are expected to fall within.

At whole building scale, it is usual to face limitations in defining system boundaries, there is little cooperation between LCA analysts and manufacturers, a general lack of understanding on how to interpret and apply LCA results, and many assessments show different results (Bribián et al., 2009). Literature indicates that if data unrelated to the assessed building region is used, the results should be considered as an approximation of the environmental impacts, rather than their true representation (Bribián et al., 2009).

Whole building LCA (wbLCA) could be enhanced by standardizing pivotal points such as system boundaries, scope definition, methodological choices and datasets, ultimately leading to the establishment of benchmarks for different building typologies (Chau et al., 2015).

Indeed, one of the IEA EBC Annex 72 (Assessment life cycle related environmental impacts caused by buildings) subtask 1 activities involves performing wbLCA of the same case study by teams from all participating countries. Reference buildings (size, materialization, operational energy demand, etc.) on which the (existing national) assessment methods are applied using national (if available) databases and (national/regional) approaches. Assessments results were compared to identify major similarities and discrepancies, for the ultimate goal of better targeting harmonization efforts and identify areas of disagreement with little or no potential for harmonization.

The assessment of the reference building is carried out by using the same material and energy demand but applying 21 different national or regional LCA approaches. Results were reported in a uniform template that allowed for comparison between the countries. The methods applied different reference study periods, service life of building elements/ components, life cycle stages included, and modelling approaches for materials' end of life treatment.

The GHG emissions of the electricity used in operation reported by the different countries differ substantially, but basically reflect the differences in GHG emissions of the electricity mixes, as electricity is the only energy carrier used. The annualized GHG emission per area unit varied across countries by a factor of 7. Emissions per mass unit of building material varied by a factor ranging between 1.6 (bricks) and 6 (reinforcing steel). As to product stage (factor of 2.6), due to the use of different databases and versions of them; use stage (factor of 5), mostly due to replacement rates; and end of life stage (factor of 12), mostly due to assumptions regarding recycling shares, waste processing and final disposal scenarios (Frischknecht et al, 2019).

This paper replicates the Annex 72 exercise at Brazilian level. Herein, two teams located in Brazil's southeast (team A) and south (team B) regions assess the reference office building and compare their findings and approaches.

Methods

Analyses in this paper refer to a passive office building designed for a temperate climate and basically composed by loadbearing masonry and steel-reinforced concrete slabs. The building's net floor area is 2,700 m², distributed over 6 floors. The advanced building concept dismissed the need of heating/cooling systems.

Both teams received the building's bill of materials, product specifications, energy and water consumption, and building information model.

The grounds for properly comparing the teams' results were agreed upon from the outset:

a. Life cycle stages addressed in the assessment, in compliance with BS EN 15978(CEN, 2011);
b. Building location, as it directly impacts transportation distances throughout all assessment phases;
c. Building's reference service life and material lifetime, to address the period that the building would be used before its demolition/ dismantling, as well as maintenance and replacements during the use phase;
d. Database selected as data source;
e. System model chosen for the assessment;
f. Software for conducting the assessment;
g. Life cycle impact assessment method;
h. Percentages of construction and demolition waste assigned to each end of life treatment considered;
i. Declaring how material wastage along the construction and replacement phases was addressed;
j. Defining adaptation rules established to adapt database processes to the study's context; and the nature and extent of adaptations made;
k. Declaring processes excluded from the assessment;
l. Stating possible limitations faced along the assessment that could affect results.

After the decision-making stage, both teams carried out their wbLCA independently, without sharing procedures and approaches prior to the results comparison phase. Only then, the teams were allowed to check each other's decisions and results, and to learn from their findings.

Throughout the LCA, both teams made the most appropriate decisions for their contexts. Every decision should be well documented, and the decision-making process should avoid relying exclusively on subjective judgment. A summary of each teams' decision-making key steps is presented on table 1. Team A addressed stages A1-A5, B4, B6, B7, C1 and C2, while team B excluded stage A5, but included stages C3 and C4. Both teams agree that differences across modules B1 to B5 are too subtle, and that B4 is best addressed by replacement rates. In that regard, the only Brazilian data available refers to minimum design service life instead of expected service life, based on ABNT NBR 15575 (2013).

Also, Team A understands that C3 and C4 modelling would heavily rely on scenario analysis and demand local data unavailable at the time of analysis. Similarly, Team B disregarded stage A5 due to lack of data.

Team B's stages C1 to C4 are calculated considering: (i) energy consumption informed in the report or estimated diesel consumption for the dismantling process; (ii) average transportation distances of 90km and 60km to landfill and recycling plant, respectively. The database transportation process is {transport, freight, lorry 32 metric ton, EURO3 GLO"}; (iii) CONAMA Resolution 307/2002 is considered for materials whose dismantling does not allow for adequate separation, using the process {inert waste - treatment of inert waste, sanitary landfill | inert waste}.

Building locations adopted are Campinas-SP (Team A) and Porto Alegre-RS (Team B). Both teams defined 50 years as the building lifecycle. The reference study period has an influence on the relative importance of the GHG emissions of manufacture, construction, replacements and end of life stages on one hand, and the operational GHG emissions on the other (Frischknecht et al, 2019).

Team A used SimaPro 8.5.2.0 under a faculty license, while Team B preferred OpenLCA 1.6.3, an open-source software. Data from the Ecoinvent database versions 3.4 (team A), 3.3 (team B), and from suitable literature (both teams) were used. Also, both teams adopted the cut-off system model in their LCA.

Team A assessed primary energy consumption and all impact categories addressed in CML-IA baseline V3.05, while Team B chose three impact categories to assess. Only global warming potential (GWP) and depletion of abiotic resources, focusing on fossil fuels [assessed by team B through the updated CML baseline v4.4 (Oers & Guinée, 2016)], were compared. About GWP, Team B considered that wood products can act in the CO_2 sequestration during the stages A1-A3 and B4 and it will be emitted at the end of life stage (C1-C4).

Team B assumed no material wastage, whilst Team A adopted regional or average values from the *Tabela de Composições e Preços para Orçamentos*, TCPO (2013), a widely used national reference for construction services composition and budgeting. Both teams relied on NBR 15575-1 (ABNT, 2015) to define the service life of components and systems. When it comes to end of life waste's destination, Team B assumed 100% would be landfilled, while Team A defined each material's destination according to ABRECON (2015) and several references available in the literature.

Team A adapted all processes employed in the assessment to the national context. A cut-off adaptation rule was established, imposing that only the background processes responsible for 80% of the impact of the foreground process would be modified. This adaptation was applied until the process was fully contextualized, or until the sixth background process level.

Team A modelled other relevant processes – 35Mpa concrete, CP5 35Mpa precast concrete, lime mortar, cement mortar, and steel and zinc coated processes – from scratch for the Brazilian context. For all other processes, a general adaptation procedure is applied in three fronts: converting all processes' electricity mixes to the national matrix, changing electricity processes to same-voltage (Electricity {BR}); replacing all water processes with corresponding national – Water, unspecified natural origin {BR}; Water, cooling, unspecified natural origin {BR} and Water, well, in ground, {BR} – or Rest of the World (ROW) processes, whenever equivalent Brazilian processes are unavailable (Tap water {RoW}). Lastly, in situations where the foreground process takes place in Brazil or in the construction site, by replacing all background processes with Brazilian {BR} or Rest of the World {RoW} corresponding processes.

Team B followed the three-step data regionalization process proposed by Morales et al. (2019). The first one is a mass composition evaluation, selecting database processes that represent 90% of the building entire mass to be adapted. The second step consists in checking if there is any process responsible for more than 5% of the building's total GWP impact among the 10% processes that have been discarded in the first step. If so, this process is considered a hotspot, and must be adapted as well. The third step is the adaptation itself, and consists of reviewing the energy matrix and fuel sources, aiming to fit the processes technology and techniques into the Brazilian context. Information regarding transportation modals and distances are adapted to the national context. This adaptation procedure is applied for concrete, reinforcing steel, brick, lime plaster, gravel, aluminum, cement mortar, and steel.

Table 1 – Assumptions made by both teams over the wbLCA *(main divergence sources highlighted in bold)*

Category	***Team A***	***Team B***
Life cycle stages	A1, A2, A3, A4, **A5,** B4, B6, B7, C1, C2	A1, A2, A3, A4, B4, B6, B7, C1, C2, **C3, C4**
Location	**Campinas - SP**	**Porto Alegre - RS**
Building's reference service life	50 years	50 years
Database	Ecoinvent **v3.4** and literature	Ecoinvent **v3.3** and literature
System model	cut-off	cut-off
LCA software	**SimaPro 8.5.2.0**	**OpenLCA 1.6.3**
Impact assessment methodology	GWP: **CML-IA baseline v3.05** Depletion of abiotic resources - fossil fuels: **CML-IA baseline v3.05**	GWP: **CML baseline v4.4** Depletion of abiotic resources - fossil fuels: **Oers et al. (2001)**
Material lifetime	Table C.6, ABNT NBR 15575-1 (2013)	Table C.6, ABNT NBR 15575-1 (2013)
Residues' final destination	According to **ABRECON 2015 and several literature sources (C1-C2 only)**	**C1-C4, 100% landfilled** (Ecoinvent dataset)
Material loss	**TCPO, adopting an average value** for materials lacking data	**No wastage**
Adaptation rules	Adapting **all foreground processes** Adapting **80% of background processes** (Pareto analysis) Adapting until the **sixth level of background processes**	Adapting **foreground processes that represent 90% of entire building mass** Adapting **GWP hotspots, processes responsible for 5% or more of the building total impact among the 10% excluded processes** Adapting until the **fourth level of background processes**. Using the ceramic national association (ANICER)'s **ceramic brick dataset**, based on from Brazilian primary data.
Adaptation details	Adapting the electricity mix to the national context (Electricity, high voltage {BR} / Electricity, medium voltage {BR} / Electricity, low voltage {BR}) **Adapting water sources to the national context (Water, unspecified natural origin, BR / Water, cooling, unspecified natural origin, BR / Water, well, in ground, BR / Tap water {RoW});** **Converting processes taking place in Brazil to {BR} or {RoW}, according to database availability** **Designing specific processes from scratch: 35MPa concrete, CP5 35MPa precast concrete, lime mortar, cement mortar, and steel + zinc coated**	Adapting the electricity mix to the national context (Electricity, high voltage {BR} / Electricity, medium voltage {BR} / Electricity, low voltage {BR}) **Adapting values, inputs, and processes: primary and secondary aluminum, ceramic brick, cement mortar, concrete 25MPa, lime mortar, reinforcing steel, steel.** **Converting values and transportation modals: sand, clinker, primary and secondary aluminum, ceramic brick**.
Excluded processes	**No processes are excluded**	**Double flooring system and vacuum insulation panel**
Limitations	Inability to obtain material-specific total results	Inability to obtain material-specific total results, **only by stage or constructive subsystem.** **Some processes are not adapted, and the LCA used some background RoW (rest-of-the-world) data.**

Results

The wbLCA results for each impact category, based on each team's decisions and procedures (table 1) are presented in figures 1 and 2.

Team A's overall results are higher than those of Team B. That would be also expected for the product stage (A1-A3), as both teams started from the same bill of materials, but the differences found might be attributed to adaptation cutoff criteria and procedure, which influenced the product inventory. Team A assessed the whole materials inventory, while team B excluded two items: Double flooring system and Vacuum Insulation Panel. Still, for abiotic depletion – fossil fuels (ADff) - the differences were about 36 % (A1-A3) and 67% (A4-A5). Building locations influence the transportation scenarios considered in the latter.

In the use phase, results for stages B2 to B5 are practically the same for both teams. That is expected, since the same replacement cycles were used, based on NBR 15575; the slight difference (~1%) results from variation in impacts carried out from product stage

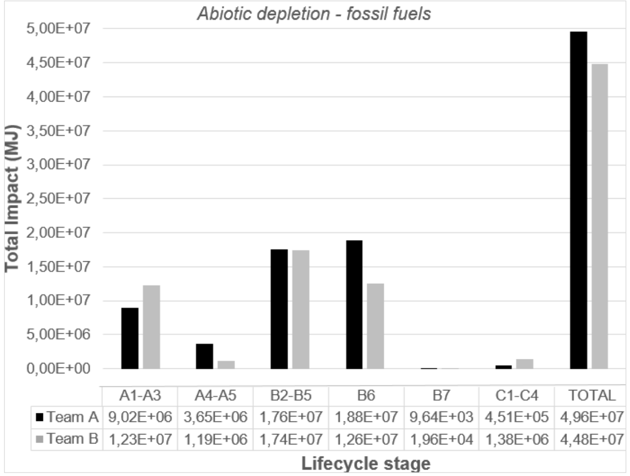
When assumptions made come into play, divergences become more prominent, as for modules B6 (33%), B7 (104%) and C1-C4 (206%). B6 and B7 were surprisingly affected by adaptation strategies.

Only team B considered carbon sequestration during bioproducts production phase. Global warming potential differences are therefore especially observed in the stages influenced by carbon sequestration accountancy, and reach about 144% (A1-A3); 68% (A4-A5), 229% (B2-B5), 184% (B6) and 13% (B7). Again, divergences are much clearer for module C1-C4, mainly because of the emission of the CO_2 sequestered by the wood elements during the life cycle of the building calculated by Team B.

For the end-of-life stage, Team A assessed only stages C1 and C2 using SimaPro, where each stage is calculated individually and seems to best capture ADff than GWP. On its turn, Team B used OpenLCA, which calculates all end-of-life modules (C1 to C4), but returns an aggregated value for the whole stage and prevent analysis of individual modules.

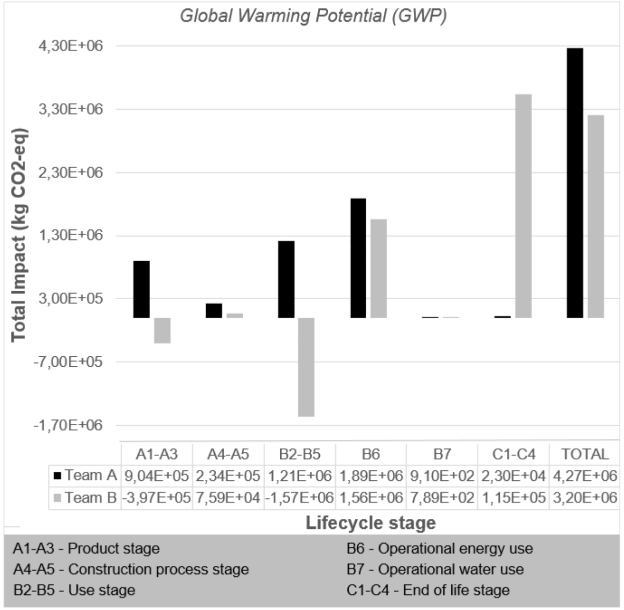
Finally, considering the wbLCA results, the differences are less expressive but still noticeable: about 10% for abiotic depletion – fossil fuels; and about 25%. for global warming potential. Such differences are related to the following: (i) cutting-off criteria (Team B excluded 2 materials); (ii) divergences in the LCIA methods used; (iii) module A5 (energy consumption and losses) is not considered by Team B; (iv) differences in the distances considered as a result of different contexts; (v) Team B adaptation may have pulled more impacting energy matrices from non-adapted levels. Furthermore, the most pronounced differences in GWP are due to modeling decisions, since Team B considers CO_2 sequestration.

Figure 1– Results comparison for abiotic resources (fossil fuels) depletion



	A1-A3	A4-A5	B2-B5	B6	B7	C1-C4	TOTAL
■ Team A	9,02E+06	3,65E+06	1,76E+07	1,88E+07	9,64E+03	4,51E+05	4,96E+07
■ Team B	1,23E+07	1,19E+06	1,74E+07	1,26E+07	1,96E+04	1,38E+06	4,48E+07

Figure 2 – Results comparison for global warming potential



	A1-A3	A4-A5	B2-B5	B6	B7	C1-C4	TOTAL
■ Team A	9,04E+05	2,34E+05	1,21E+06	1,89E+06	9,10E+02	2,30E+04	4,27E+06
■ Team B	-3,97E+05	7,59E+04	-1,57E+06	1,56E+06	7,89E+02	1,15E+05	3,20E+06

Conclusions

In this paper, we showed how the lack of a national protocol and proper guidance on whole buildings LCA can lead to divergent procedures and results. The same assessment was carefully carried out by different analysts. One cannot really state that any of those would be incorrect. Yet, results vary.

Unavoidable decisions were made regarding the missing life cycle inventory data for specific materials (e.g. 'vacuum insulation panels') and different aggregation levels in the information provided and in the data available (e.g. in the product level, such as reinforced concrete, instead of having separate LCI data on concrete and reinforcing steel) and the life cycle stages (e.g. data only available for the whole life cycle and not broken down into Stages A, B and C or their modules). Furthermore, differences in the units of the building data and the available LCA data (e.g. pieces vs. m3 of stairs) required conversions using factors chosen by each team.

Over the course of a wbLCA analysts often need to make arbitrary choices based on their own experience and judgement. Indeed, to overcome the lacking LCI data, the authors used proxies, EPDs or disregarded the material and/or building elements (e.g. 'vacuum insulation panels' and double flooring system).

Also, the lack of a solid national database imposes that the analyst gathers primary data, adapts international LCA data and processes to the study's context or seeks international guidance and information sources. As adaptation procedures are not standardized, the approach and detail levels involved in such contextualization depend on the analyst's judgement.

In the present study only two impact categories, analyzed by two teams, were discussed. Other impressions could be extracted for a wider range of impact categories, following different patterns, and by applying varied software.

Our experiment confirms that unstandardized LCA may drive analysts insane, as results discrepancy seem unavoidable even when apparently doing the 'same thing' multiple times - or by multiple teams. However, the greatest insanity is probably to aim for advancing the wbLCA practice without seeking ways to harmonize methodological and modeling approaches.

Possible avenues for future research are the replication of a similar challenge by other Brazilian teams in different regions, using different software, and adaptation and modelling criteria. Besides that, more verifications regarding sensibility to modeling choices are required, as well as the proposition of a framework to guide the data adaptation process and modeling choices within wbLCA.

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References

ABRECON. Pesquisa Setorial 2014/2015 da Associação Brasileira para Reciclagem de Resíduos da Construção Civil e Demolição (2015). Available at <https://abrecon.org.br/pesquisa_setorial/>

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. Edificações Habitacionais – Desempenho. ABNT NBR 15575, Rio de Janeiro, 2013.

Bribián, Z.B., Usón, A.A., Scarpellini, S. Building and Environment (2009). https://doi.org/10.1016/j.buildenv.2009.05.001

British Standards Institution (2011). BS EN 15978:2011. Sustainability of construction works: assessment of environmental performance of buildings: calculation method. London.

Chau, C.K., Leung, T.M., Ng, W.Y. Applied Energy (2015). https://doi.org/10.1016/j.apenergy.2015.01.023

CONAMA Resolution 307/2002 - "Estabelece diretrizes, critérios e procedimentos para a gestão dos resíduos da construção civil". – Resolution's date: 07/05/2002 -DOU pub.136, from 07/17/2002, p 95-96.

Frischknecht, R. et al. Comparison of the environmental assessment of an identical office building with national methods. 2019 IOP Conf. Ser.: Earth Environ. Sci. https://doi:10.1088/1755-1315/323/1/012037

Gantner, J.; Wittstock, B.; Lenz, K. et al. (2015). EeBGuide Guidance Document Part B: Buildings. Operational guidance for LCA studies of the Energy Efficient Building Initiative. Stuttgart: Fraunhofer Verlag.

Morales, M.; Moraga G.; Kirchheim A. P; Passuello. J Clean Prod (2019). https://doi.org/10.1016/j.jclepro.2019.117869

TCPO. Tabela de Composições de Preços para Orç. (2013). SP: PINI.

Van Oers, L., Guinée, J. Resources (2016). https://doi.org/10.3390/resources5010016