When good enough is best:
Simplified LCA for fast and reliable environmental assessment in medium-economy countries

1) Abstract:

The construction sector generates large amount of waste and is generally considered as an important contributor to climate change. It induces as well irreversible changes in local eco-systems. To face these challenges, industries invest into so-called “green innovations”, and national or local public authorities are demanding scientifically based decision support. Within the available environmental assessment methodology, the Life Cycle Assessment (LCA) has been widely accepted as a relevant method and it led to the development of different sector-specific guidelines, databases and tools in several countries and mostly in Europe. However, such developments are up to now, not completely implemented in other countries and it may not be relevant to do so given the huge number of environmental information required in existing LCA databases. If the aim is to have a widespread use of LCA in the construction sector especially in Latin America countries, it is probably good enough to focus on the most relevant environmental flows (e.g., carbon dioxide, waste flows…) found critical for the building sector. The limitation of the number of environmental flows to collect then allows spending more resources on the characterisation of the highly variable natural resources routes and building materials’ manufacturing processes. By doing so, the use of LCA can be sized up while focusing on the most relevant environmental impacts. The Swiss and Brazilian teams are willing to promote the use of a simplified LCA method based on forefront measures in order to grasp the variability of the field as well as an identification of the most critical process that should be reconsider in standard LCA database.

2) Relevance, objective and justification:

The increasing world population, urbanisation and construction-industry boom over the last 50 years have led to systematic over use of resources and energy (IPCC, 2007), and this increased demand for natural resources is now a threat to global economic and social equilibrium (Stern, 2006). The building sector is a major contributing sector of human activity affecting energy and resource depletion. In reaction to this overexploitation of material and energy resources, there has been a call for increasing awareness of the environmental impact of the various human activities, leading to the development of so-called low-CO_2 solutions for construction materials like cement-based materials (Scrivener et al, 2016). In parallel, the need for appropriate environmental assessment methodology of human activities is growing (Rockström et al, 2009). One of the methods suggested to evaluate such environmental impacts is Life Cycle Assessment (LCA). LCA provides a holistic approach already applied in the construction sector that is based on studying “the whole industrial system involved in the production, use and waste management of a product or service” (Baumann et Tillman, 2004). Policy makers use LCA to choose environmental strategies (Baumann et Tillman, 2004).

However, many uncertainties exist on the result of building's LCA. Numerous studies have already highlighted the fact that, the energy during the use phase of the buildings (e.g. 30 to 80 years) as well as its environmental impact will drastically be reduced during the next 50 years (Georgiadou et al., 2012) either due to future climate change (Olonschek et al., 2011) or to societal transformation (e.g. The Swiss 2000-Watts Society initiative). A growing agreement in the building LCA community is on the increased contribution of building materials on the total environmental impacts (Kellenberger and Althaus, 2009). In developed countries, it is due to the better energy efficiency of buildings, while in developing countries, the climate as well as the income level reduce the consumption of energy during the operation of buildings increasing then the contribution of the building materials in the building's life cycle.

The quality and comprehensiveness of datasets for raw materials used for the environmental assessment of building materials is then a fundamental topic.

Natural raw materials and industrial processes are intrinsically variables. Spatial variation of extraction practices can be noticed in the different part of the world due to either geological or human factors. Currently, a same technological route for a building material results in similar environmental impacts because of the low amount of LCA data available worldwide. Promising studies in Latin America and especially in Brazil show that at each time, a larger sample is analysed, the variability of the environmental results become visible (Oliviera et al, 2016). This approach required to meet the world environmental agreement (e.g., Paris agreement), will only be possible if we make LCA simpler.

To do so, the analysis of the supply chain is necessary and has already been raised (Gomes et al., 2013). Indeed, an industrial material and the data available concerning that material are the result of many different processes that we often separate between foreground process (or data) linked with the directly measurable actions and the background processes (or data) linked with processes occurring far from the production plant, earlier in the supply chain. For instance, the quality of cement data is dependent on the quality of the assessment made for the extraction and refinement of fuels (Chen et al., 2010), which is a process occurring geographically and technologically far removed from the cement industry.

In LCA, it is common to use generic database to get the data for the background processes. The quality of these background data is difficult and time consuming to assess because the data are linked to processes far removed from the evaluated product. In the case of industrialised materials, it is often considered that background data derived from a standardised process that may be similar in different industrial plants. Thus, the low quality of background data can be ignored. As a result, assessing the environmental impact of one cement plant enables generalisation, with a high level of confidence, concerning the environmental impact of a cement bag produced in another plant, as long as the plants operate under the same processes (Bösch et al., 2007), even if changes in environmental impact due to intrinsic variability in the processes cannot be avoided (Chen et al., 2010). This assumption is probably too optimistic when dealing with three aspects.

The first one is the fact that an industrialised process is still controlled by manmade practices and that there is an inherent variability in these practices. It has been very well illustrated in the concrete block survey variability Brazil (Oliveira, 2015).

The second one is that the overall impact is sometimes controlled by a background data that has been very roughly modelled in the database and where impacts could be easily divided by a factor 10 or 100 due to the very high uncertainty on the real data.
The last point is for low-industrialised materials, such as bamboo, which are often produced in rural communities with low quality control, where the potential human factor is significant (Zea and Habert, 2015). Previous studies of low industrialised products have also highlighted this point for the lumber coming from Amazon (Ferraz de Campo and John, 2012).
The applicability of LCAs could then be greatly improved if less information with relatively high reliability could be used to compare or improve production processes. Actually, the tendency to use fewer indicators while achieving accurate results is gaining adepts within the LCA community. For instance, Switzerland developed a single indicator that is now used at the federal level to support environmental decision making (Frischknecht et al, 2009). Recent studies in the LCA community show that a reduced number of non-correlated environmental flows can be related to 4 to 5 environmental impact priorities (fossil fuels, waste/land use, water and toxicity) (Lasvaux et al., 2016).

The objective of this project is to **identify the critical parameters to take into account in the development of an environmental database of construction materials for medium-economy countries**. This database will be a simplified LCA with reduced data collection at manufacturing sites in order to be largely used in the construction sector with very low additional costs, allowing identify variability of environmental impact among producers of a same product.
To do so, we will combine two strategies that are developed in both countries. The Swiss partners will work on the existing environmental database, initially developed in Switzerland but now internationally used (ecoinvent). They will identify the sensitivity of the data to background processes and uncertainties in the production. The Brazilian team will measure the foreground data on construction site and materials production plant. The combination of the two will allow to develop a robust and simple database. Finally, the development of this database will also be associated with the justification of an assessment method to be used in medium-economy countries. This will be done to a reduced set of indicators that have been identified by both teams including at least the climate change, resource/waste and water impact categories.

3) Research plan and timeframe

To achieve our objective, the research plan will be developed in different steps and initiatives that will be ultimately combined at the end of the coming year.
The first task will be to go through a sample of the ecoinvent processes related to the construction industry and to identify depending on the environmental impact category what is the contribution of the foreground processes and what is the contribution of the background data. Once this task is done, it will be possible to identify to which industry, the background processes are related. Then, we can start ranking the assumption behind their quality (the pedigree matrix of ecoinvent will be used).

In parallel, the assessment of low industrialised materials such as earth, bamboo, straw as well as more conventional material, bricks, or fibrocement panels will be evaluated through an uncertainty analysis and sensitivity analysis on their production process.

These two analyses based on the ecoinvent database will allow to identify building materials which will be highly sensitive to changes in country and to weak background data measurement.

The results will be presented in a workshop in São Paulo where the Brazilian team will present their initial results on the measures done on construction site (waste, water, cement consumption). During this workshop and considering the initial work done, we will target specific materials where there is a crucial need for real onsite measurement. This will also be done in production plants and in industry that are related to the construction sector but not necessarily from the construction sector.

This data collection will be done until September 2018 while the Swiss team will refine the results on the ecoinvent background processes.

In October 2018, a second workshop will take place in São Paulo, where the Brazilian team will present their results. This will allow a synthesis of the work done and a presentation of a first draft of a reliable environmental database for Brazilian construction sector. This will also set up the preliminary results for further fundings either from the Swiss development and cooperation agency or from the Brazilian research agency.

List of milestones : *Outline major milestones and related activities*[1]

Milestones	***Related activities***	***Expected date***
For Swiss partner 1	Identification of foreground and background contribution in ecoinvent processes.	03.2018
For Swiss partner 2	Gathering of sensitivity analysis for low industrialised products modelled with Ecoinvent database	03.2018
1st workshop in São Paulo	Presentation of activities and identification of needs for further development	04.2018
For Brazilian partner	Finalisation of data collection in construction site and production plant	09.2018
2nd Workshop in São Paulo	Synthesis and definition of further actions	10.2018

4) Expected impact and follow-up activities

The long term objective of this SEED project is to justify that this combination of approach is valuable for a further implementation of environmental assessment in the construction sector. This would then allow the Swiss-Brazilian team to apply for larger research programs. Either from the Swiss development agency for the implementation of the method and the adaptation of the Swiss Ecoinvent database in the Brazilian context of from the Brazilian Research agency (CNPq) in order to develop an innovative environmental assessment method in countries without existing database.

5) Research collaboration

[1] Please insert additional rows into the table if required

The research team gathered has already worked together and learned about the work activities of the others. The participation to common working groups at the international level (e.g., IEA, RILEM, UNEP) as well as regular visits between Brazil and Switzerland allows having a good understanding of the research activities of the other members. Furthermore, a Brazilian PhD student from the Brazilian group will stay this year at ETH with an excellence scholarship funding to refine the calculation on water scarcity indicator. This can trigger very fruitful synergies with the Seed project.

6) Experience of the applicants

The Brazilian and the Swiss team have been working in the field of LCA since 15 years and are involved in different institutions at the international or national level to promote a comprehensive way of dealing with LCA. The Brazilian team is co-chairing the Sustainable Building and Climate Initiative of UNEP building materials working group on Low-Carbon Eco-efficient Cementitious Materials, which is seeking for new solutions to mitigate CO_2 in the cement value chain. The group is also coordinating the Building Materials and Components Working Group of the Brazilian National LCA Project, which is developing a national LCA standard, compatible with the ISO LCA system. The Swiss team has been an active member of Annex 57 from the International Energy Agency on embodied energy of buildings and is now heavily involved in the new Annex 72 on LCA of buildings. The group leader has been involved in many European projects and standardisation aspects linked with the implementation of Environmental Product Declaration (EPD) for construction products in France or Germany.

In all these groups and related research projects, the Swiss and the Brazilian partners have promoted a simplified way of assessing the environmental impact. On the question of the impact assessment methods, the number of indicators has been scrutinised by statistical methods. The pertinence of the indicators for the specific construction sector has also been studied. Especially considering the resource depletion aspect. Considering the assessment of sustainability in Buildings, the certification label developed in Brazil Selo Casa AZUL which is not asking for a complete LCA, but rather simplified information on the amount of cement or steel in the construction which at the end allows a general understanding of the main impact at a very low additional cost has been co-developed by the Brazilian team. All these studies allow us to be aware of the necessity of having a coherent, simplified and still accurate environmental assessment method. The objective of the current proposal is to gather those different expertise and build a comprehensive strategy for a further implementation of LCA in non-European countries. Eventually, the framework developed in this project could be proposed to some international working groups (e.g., UNEP).

7) Inclusion of female researchers and promotion of young researchers

PhD students that will work from the Brazilian team at ETH with the excellence scholarship is a woman. In both groups Brazilian and Swiss, the gender balance is actually a priority and the team are in majority feminine.

8) Intended Intellectual Property Rights, Ethical, safety and regulatory issues:

Not relevant

9) References

Baumann, H., and Tillman, A.-M. 2004. The hitch hiker's guide to LCA: an orientation in life cycle assessment methodology and application. Student litteratur publisher: Lund, Sweden.

Bösch, M., Hellweg, S., Huijbregts, M., Frischknecht, R. Applying cumulative exergy demand (CExD) indicators to the ecoinvent database. 2007. Int. J. Life Cycle Assess. 12 (3), 181-190

Chen C., Habert G., Bouzidi Y., Jullien A. 2010. Environmental impact of cement production: Detail of the different processes and cement plant variability evaluation. Journal of Cleaner Production, 18, 478-485.

Damineli B., Kemeid FM., Aguiar PS., John VM. 2010. Measuring the eco-efficiency of cement use, Cement and Concrete Composites, 32, 555-562

Ferraz de Campo, E., John, V.M., 2012. Co2 emissions and residues of Amazon rainforest lumber e preliminary results. In: International Symposium on LCA and Construction. Nantes, France.

Frischknecht, R., Steiner, R., Jungbluth, N., 2009. The Ecological Scarcity Method Eco-factors 2006, a Method for Impact Assessment in LCA. Federal Office for the Environment (BAFU), Zürich, Swtizerland.

Georgiadou M., Hacking T., Guthrie P. 2012. A conceptual framework for future-proofing the energy performance of buildings. Energy Policy, 47, 145-155.

Gomes, F., Brière, R., Habert, G., Feraille, A., Lasvaux, S., Tessier C. 2013. Adaptation of environmental data to national and sectorial context: application for reinforcing steel sold on the French market. International Journal of Life Cycle Assessment, 18, 926-938

Habert, G., Bouzidi, Y., Chen, C., Jullien, A. 2010. Development of a depletion indicator for natural resources used in concrete. Resources, Conservation and recycling, 54, 364-376.

Hoxha E., Habert G., Chevalier J., Bazzana M., Le Roy R. 2014. Method to analyse the contribution of material's sensitivity in buildings' environmental impact, Journal of Cleaner Production, 66, 54-64.

Ioannidou D., Nikias V., Brière R., Zerbi S., Habert G. 2015. Land-cover-based indicator to assess the accessibility of resources used in the construction sector. Resources, Conservation and recycling, 94, 80-91.

John VM., Prado R.T.A. 2010. Selo Casa Azul Manual. Good practices for a more sustainable housing 1. ed. São Paulo: Paginas & Letras, 204pp. (www.caixa.gov.br/Downloads/selo_azul/Selo_Casa_Azul.pdf)

Kellenberger D. and Althaus H.J. 2009. Relevance of simplifications in LCA of building components. Building and Environment, 44, 818-825

Lasvaux S., Peuportier B., Chevalier J., Habert G. 2016. Correlations in Life Cycle Impact Assessment (LCIA) methods and indicators for construction materials: what matters? Ecological Indicators, 67, 174-182

Lasvaux S, Schiopu N, Habert G, Chevalier J, Peuportier B. 2014. Influence of simplification of life cycle inventories on the accuracy of impact assessment: application to construction products. J. Clea. Prod., 79, 142-151

Oliveira, L. S Life Cycle Analysis of Brazilian Concrete Masonry And Paving Blocks (in Portuguese). Escola Politécnica, University of São Paulo, 2015 157p.

Olonschek M., Holsten A., Kropp J. P. 2011. Heating and cooling energy demand and related emissions of the German residential building stock under climate change. Energy Policy, 39, 4795-4806

Rockström J. et al. 2009. A safe operating space for humanity. Nature 461, 472-475

Stern N. 2006. Sterns Review on The Economics of Climate Change (pre-publication edition). HM Treasury Executive Summary. London.

Scrivener K L., John V. M., Gartner E M. 2016. Eco-efficient cements: Potential, economically, viable solutions for a low-CO2, cement-based materials industry, UNEP, 64 p.

WBCSD Mainstreaming Life-Cycle Analysis for Building Materials. Accessed 23 Octobre 2015 http://wbcsdforms.wbcsdservers.org/portfolio-item/mainstreaming-life-cycle-analysis-for-buildings-and-materials/