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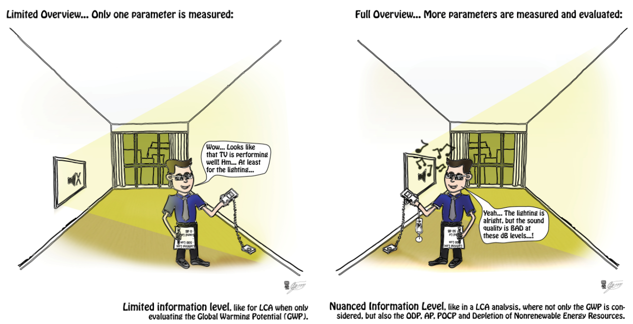
Life Cycle Assessment (LCA) for Buildings

CURRENT vs. LCA

The current environmental impact analysis narrowly focuses only on CO_2 emissions, which is akin to watching television by only looking at the display of a light meter. In contrast, an LCA analysis gives a much more nuanced information, akin to watching the television



CURRENT Analysis	LCA Analysis
CO_2 emissions from operational energy consumption (of buildings), not including the life-cycle assessment	**1) Global warming potential (GWP), in kg CO_2-equ.** Increase in greenhouse gas concentrations, resulting in increases in global average surface temperatures. **2) Depletion of stratosphere ozone layer (ODP), in kg CFC-11.** Reduction of ozone concentration in the stratosphere which filters out UV-B radiation leading to health hazards. **3) Acidification of land/ water (AP), in kg SO_2.** Emissions which increase acidity of water and solids, e.g. acid rain. **4) Eutrophication (EP), in kg phosphate.** Refers to the addition of nutrients causing excessive biomass growth and decay in water or soil, resulting in oxygen depletion. **5) Formation of tropospheric ozone (POCP), in kg O_3-equ.** Smog is formed by radiation from the sun causing ozone to build up in the lower atmosphere; harmful to humans, crops and buildings. **6) Depletion of nonrenewable energy resources, in MJ.** Does not renew itself at a sufficient rate for sustainable economic extraction in meaningful human time-frames, e.g. coal, gas, oil, uranium.

A NEW and more nuanced method of evaluating green buildings is starting to get used in Malaysia. It is called Life Cycle Assessment (LCA) and focuses on a wide array of different environmental impacts of building materials during the course of a building's lifetime.

The environmental focus has so far mostly been limited to climate change where the building sector accounts for a staggering thirty percent or more of the global greenhouse gas emissions. These emissions are primarily related to the building energy consumption used to cool, heat and power the buildings. As we are making the buildings more energy efficient and putting solar panels on the roof, the environmental impact of the building materials starts to play a relatively greater role, hence, making LCA increasingly relevant. For example, the latest version of the American green building certification tool, LEED v4, now incorporates LCA optimization of buildings.

The six LCA parameters, used by LEED, give a nuanced environmental impact assessment, going far beyond just looking at CO_2 emissions.

What is LCA?

LCA is a tool for assessing the environmental impacts caused by a product during its whole life cycle. This means accounting for several different environmental impacts stemming from the raw material excavation, the manufacturing process, the usage and the disposal in the end (cradle to grave). Therefore the inputs and outputs of materials and the associated energy consumption for each process needs to be analyzed carefully and put into a database. This allows for a detailed environmental impact analysis of different building solutions, for example, the environmental impact of using brick walls versus using concrete walls.

Step	Life-cycle assessment (LCA)
1	The goal and scope definition determines the functional unit which enables a comparison in the end and the system boundary which is a subjective choice and describes which processes are included in the calculation.
2	The inventory analysis (LCI) compiles the relevant inputs and outputs of every stage in the life cycle referring to the raw materials, energy usage and transportation.
3	The impact assessment (LCIA) determines the different emissions and classifies them to impact categories as for example CO_2, CH_4, CO, N20, CF_4 all belong to the Global Warming Potential.
4	Qualify and evaluate the results which will lead to direct applications as LCA is not just about the obvious information on a product. It is more about analyzing the complex background ***(refer to cartoon illustration).***

Table: The four steps of LCA analysis

Perspective of LCA

One practical way to use LCA is as a management tool. As building materials are produced differently across the World, the LCA material database should ideally be country specific to get the most accurate results. For Malaysia, however, there is not yet a comprehensive LCA database for building materials, so the LCA analysis must for now draw upon overseas material databases. Once the detailed LCA material database is in place, local manufactures are encouraged to obtain Environmental Product Declarations (EPDs) in order to meet the rising market demand for green products. This demand for EPDs is currently driven by green building certification schemes like LEED, where whole-building life-cycle assessment since 2016 has been included in the "Material & Resources" category. Under LEED, a building project will be rewarded for undertaking LCA optimization of the building material selection, insofar it achieves a 10% reduction of the environmental impacts in at least three of the six LCA parameters (listed above); one of which must be the global warming potential parameter (GWP). Moreover, none of the LCA parameters must increase by more than 5% compared to the baseline building.

In the future, it is plausible that EPDs will become mandatory by law for all major building materials in an effort to reduce the overall environmental impact of the building sector. This can be achieved by legislating for the widespread use of LCA as a management tool in the building sector as well as for other sectors.

Malaysian LCA Case Study

In the following case studies, the LCA method is applied to some ongoing commercial building projects in Malaysia, namely high-rise office buildings and a shopping mall. For the LCA analysis, the majority of the building material quantities were entered as accurately as possible relating to the building structure, the building envelope and the paint. Excluded from the analysis were the mechanical, electrical and plumbing services, the building site, waste management as well as the tenant fit-out. The life-cycle of the building was set to 50 years and the environmental impact assessment breakdown from the building materials is given below:

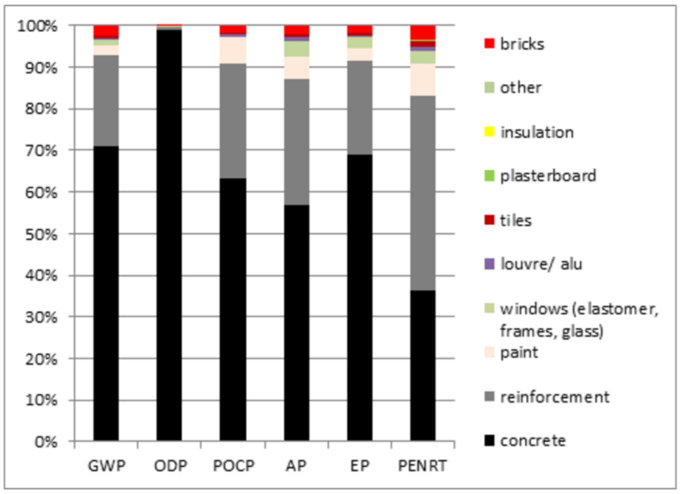


Table: 50-year LCA impact of shopping mall in Malaysia

Interestingly, in the above figure it can be seen that the bulk for the environmental impact comes from the structural elements of the building. It is the concrete and the reinforcement steel that together accounts for more than 80% of the environmental impact in each of the six environmental categories. In terms of environmental impact, the quantities for each of the six categories are listed below:

LCA indicator	Description	Unit	total/m²a
GWP	Global warming potential	kg CO2 equiv.	41.51
ODP	Ozone depletion potential	kg R11 equiv.	8.80E-08
POCP	Formation of tropospheric ozone	kg ethene equiv.	8.08E-03
AP	Acidification potential	kg SO2 eqv.	0.0721
EP	Eutrophication potential	kg PO4 equiv.	9.60E-03
PENRT	Depletion of nonrenewable energy resources	MJ	270.96

Figure: 50-year building material LCA breakdown analysis for shopping mall in Malaysia

When analyzing two high-rise office buildings, we found similar results for the global warming potential (GWP) parameter, namely a value around 40 kg CO2-equ/(m^2*year). But how does this relate to the environmental impact from the operational energy of buildings? We set out to investigate this by applying the energy intensity (BEI) of buildings in Malaysia. An average Malaysian office building has a BEI of 210 kWh/m2*year, whereas an energy efficient office has a BEI of 90 kWh/m2*year. The latter figure is obtained for the energy bills from the recently GBI Platinum rated KKR2 office tower in Kuala Lumpur.

In order to establish the GWP from the operational energy, the energy mix of peninsula Malaysia's electricity production was applied to three cases of Malaysian office buildings:

- *Case 1: BEI of 210 kWh/ m2*year. Status quo building ("current")*
- *Case 2: BEI of 90 kWh/ m2*year. Energy efficient building ("already built")*
- *Case 3: BEI of 90 kWh/ m2*year. Energy efficient building using green building materials ("future")*

The results of the analysis are:

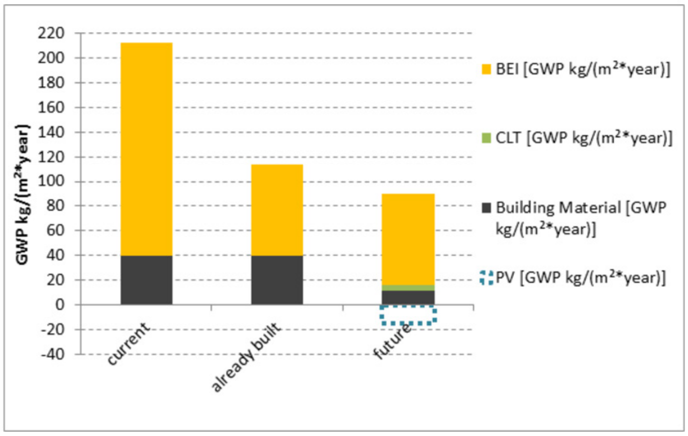


Figure: 50-year GWP analysis for Malaysia office buildings (3 cases)

The figure shows that for normal office buildings ("current") the bulk of the GWP impact is caused by building's energy consumption (BEI). However, for an energy efficient office building ("already built"), the impact from the building materials starts to matter with building materials accounting for 1/3 of the GWP impact, which justifies the use of LCA to identify ways to reduce the environmental impact from building materials. This is exactly what has been done in case 3 ("future"), where the conventional structural system of reinforced concrete is replaced by Cross Laminated Timber (CLT). Likewise, brick walls are also replaced by CLT. As concrete, reinforcement steel and bricks make up 70% of the GWP impact, the introduction of low-impact CLT causes a significant drop in the GWP value. Interestingly, the CLT stores more CO2 in the timber construction than the CO2 emitted in the manufacturing process. A negative GWP impact for CLT is therefore possible depending on the choice of insulation and plastering. Lastly, the GWP can be reduced even further by onsite energy production, for example through installation of photovoltaic panels (PV).

Looking ahead

The use of LCA is in its infancy in Malaysia, but it is here to stay. Sure indicators include the increased use of LCA overseas, as well as its incorporation in LEED – the most internationally recognized green building certification, which is also used for numerous projects in Malaysia.

In the global quest to reduce the environmental impact through energy efficiency and renewable energy programs, LCA becomes an important tool to ensure that the environmental impact reduction follows suit. For energy efficient Malaysian office buildings, a significant portion of their global warming contribution (1/3) comes from the building materials. As shown by this article, LCA can be used to quantify how the environmental impact can be significantly reduced by using low-impact building materials, particularly relating to the structural system of buildings.

For effective application of LCA in Malaysia, a comprehensive LCA database with values relevant for materials found in Malaysia should be established. This would allow Malaysian manufacturers to create Environmental Product Declarations (EPD) which cover all environmental information on a product. This would ease the incorporation of materials manufactured in Malaysia in the calculation of LCA and increase the understanding of the complex environmental impacts. Classic LCA studies might be extended with social and economical aspects to ensure that a product is suitable for the needed field. Therefore a product could have less environmental impacts but might be directly linked to health issues. The global community faces pressing and urgent environmental issues with LCA being an important part of the toolbox. Let's start to use it!

Sources:

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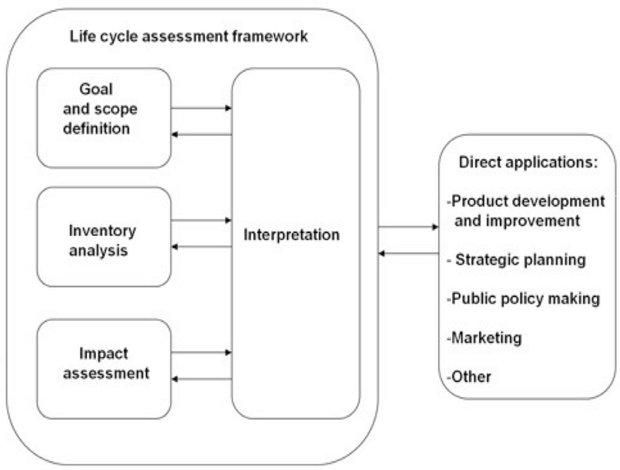

Figure: Conceptual Framework on LCA

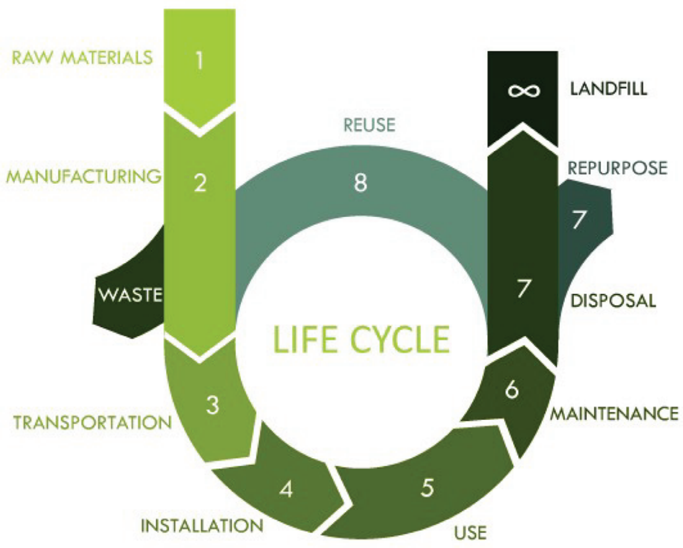

Figure: Processes included in life-cycle assessment (LCA)