ENVIRONMENTAL LIFE CYCLE ASSESSMENT OF OFFICE BUILDINGS – ANALYSIS OF DETERMINANTS

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Summary

The rising amount and diversification of green building rating systems causes environmental life cycle assessment (LCA) at the same extent. The definition of ambitious and accomplishable threshold and target values for various LCA indicators is quite difficult, due to relatively small data sets. The Austrian Green Building Council (ÖGNI), which adapted the DGNB system to Austrian requirements, has certified several buildings within the different system schemes. An analysis of certified office and administrative buildings should indicate first tendency and give suggestions for improvement. The investigation focuses on the share of the construction and utilisation phase in the defined ecological indicators. Beside the environmental impact of used materials an analysis of relevant determinants (surface-to-volume ratio, building size, energy efficiency class, basement garage, etc.) highlight further steering parameters and possible benchmarks.

Keywords: LCA, office buildings, benchmarks, DGNB, threshold values

1 Method and data collection

Assessing life cycle wide environmental impacts, LCAs generally can be applied to identify opportunities to improve the environmental performance of products and services [1]. Due to the complexity of buildings in terms of building types, materials etc. no scenarios for the optimization of building construction or materials have been developed within this study. Instead, the energy consumption of the operation phase and the construction pahse has been analysed more closely.

Nine office buildings of the first certified projects of the ÖGNI pilot phase have been assessed utilising the LCA method. The underlying standards are the general framework of CEN TC 350 for sustainability assessment of buildings and the ISO 14040 group for life cycle assessment, [1] and [2]. All LCAs in this study have been calculated regarding the simplified calculation method as specified in the ÖGNI criteria set for environmental quality, [3]. The mass balance of the buildings was used as source for the assessment of the construction phase and the energy performance certificate was the relevant source for the operational phase. The life cycle impact assessment (LCIA) was recalculated, due to different approaches in maintenance and replacement as well as credits for the end of life.

For all buildings the LCIA was calculated with the dataset of Ökobau.dat 2009 as it is free of charge and contains a huge amount of building related materials and processes. The analyzed LCA indicators are carbon dioxide equivalents, acidification, eutrophication, ozone depletion and photochemical ozone creation. The primary energy input, renewable and non-renewable, has been assessed in addition.

2 Results

The results of the life cycle impact assessment (LCIA) demonstrate that the operational phase causes 54 % up to 83 % of negative environmental impacts measured by the selected environmental indicators on average. Figure 1 shows the share of the construction including the maintenance and replacement as well as the share of the operational phase over 50 years reference life cycle. The buildings are aligned according the energy efficiency class (EEC) and the star sign '*' indicates a basement garage. The energy efficiency class is defined by the OIB-Directive 6:2007, the Austrian implementation of the Energy Performance of Buildings Directive (EPBD) and indicates the calculated useable energy demand for space heating only, [4]. Figure 1 highlights clearly, that the heat energy demand of an office building has no indication for the share of the operational phase.

Similar results can be derived for carbon dioxide equivalents (GWP) and the total primary energy input (PEI).

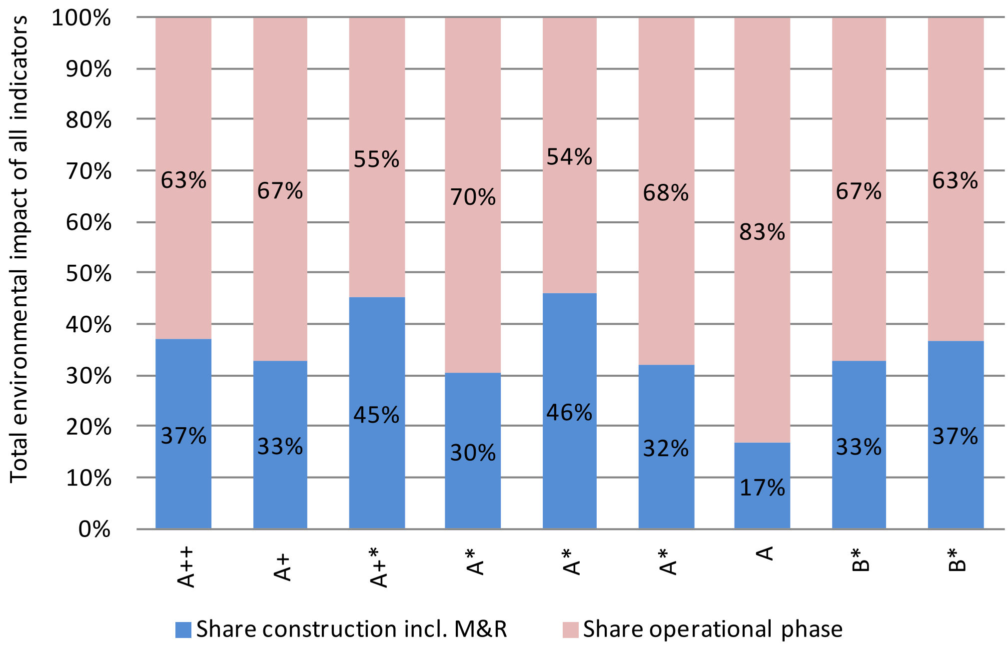

Fig. 1 *Share of operational phase vs. share of construction incl. M&R of the analyzed buildings. A++ to B = energy efficiency class, M&R = maintenance and replacement, [5]*

Considering that the share of the operational phase is on average 65 % a basement garage becomes important. On the one hand the construction is included in the LCA, but on the other hand the energy demand of a basement garage is not included in the operational phase as the OIB-Directive 6:2007 focuses on conditioned floor spaces. However the specific LCA indicators are calculated by net floor area (NFA). As the NFA of basement garages has a considerable share of the total NFA usually, the LCA results are better for buildings with garages than for buildings without garages.

Analyses on geometry of buildings demonstrate that an increase in net floor space and a decrease in the surface-area-to-volume ratio result in declining specific environmental effects. Figure 2 shows the results for total primary energy input compared to surface-area-to-volume ratio. The two outlier on S/V ratio 0,25 and 0,35 were examined more closely. The building with the S/V ratio of 0,25 is an good example for the maximum optimization of the final energy demand by implementing waste heat recovery, demand tailored building services, minimised cooling loads, etc. The building with the S/V ratio of 0,35 was constructed with ecological materials and has a very low environmental impact for the construction. But the energy demand wasn't optimized, especially the cooling and ventilation systems, thus the total environmental performance of this building is quite poor.

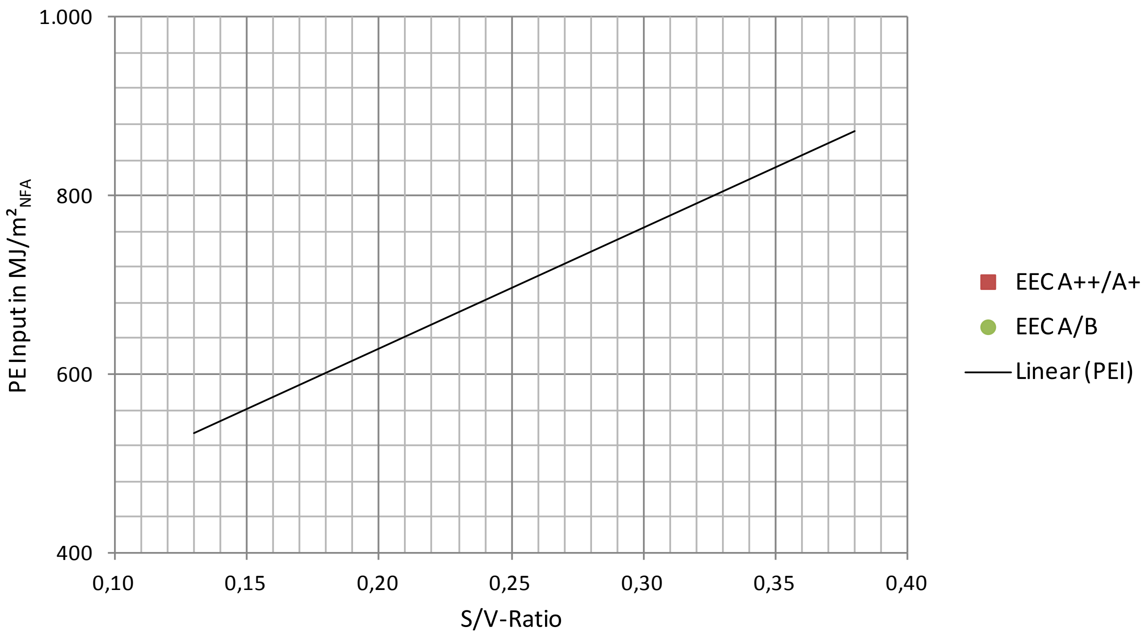

Fig. 2 *Primary energy input (total) vs. surface-area-to-volume-ratio of the analyzed buildings and linear interpolation. EEC = energy efficiency class (space heating demand), [5]*

3 Conclusions

Given the importance of the operation phase, the reduction of energy consumption needs to be prioritized via high standards in energy efficiency and the application of renewable energies (when feasible). The energy for space heating demand is not a proper benchmark for energy efficiency of office buildings. More important is the final energy demand of all building services. The recast of the OIB-Directive 6:2011 introduced new performance figures and reflects the results of this study. An open issue is the energy demand of basement garages. To compare different buildings in equal measure on specific values either their energy demand has to be considered in the operational phase or their NFA should be subtracted. Similar claims can be found in other studies also. An extensive discussion on LCA methodologies including functional unit, system boundaries and processes as well as cut of rules can be found in the European LORE-LCA project [6].

An integrated planning process such as the Integrated Energy Design seems to be reasonable, as the two outlier demonstrate. First of all the final energy demand should be optimized throughout the whole year regarding the buildings' utilisation. Next the building construction including materials is a determining factor. In this regard, LCAs contain significant potential given their comprehensive set of indicators and quantified results on environmental impacts. LCAs are useful for optimization of the environmental impact, but only combined with life cycle costing (LCC) they will be accepted in the code of practice of the real estate industry broadly.

Acknowledgement

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References

[1] *ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines.*

[2] *EN 15643-2:2011 Assessment of buildings – Part 2: Framework fort he assessment of environmental performance.*

[3] *Austrian Green Building Council: ÖGNI Steckbriefe 1 to 5 and 10 to 11. ÖGNI Scheme Office Buildings 2009. Linz, 2010.*

[4] *OIB-Directive 6:2007: Energieeinsparung und Wärmeschutz.*

[5] *Sellner, G.: Ökobilanzierung von Bürogebäuden – Analyse von Einflussfaktoren auf negative Umweltauswirkungen, Master Thesis, BOKU – University of Natural Resources and Life Sciences Vienna, 2012.*

[6] *Peuportier B.L.P., Herfray G., Malmqvist T., Zabalza I., Staller H., Tritthart W., Wetzel C., Szalay Z.: Life Cycle Assessment Methodologies In The Construction Sector – The Contribution Of The European Lore-lca Project; France, Sweden, Spain, Austria, Germany.*
[World Sustainable Building Conference, Helsinki, October 18–21, 2011] In: Finnish Association of Civil Engineers RIL, Proceedings Vo. 2; ISBN: 978-951-758-534-7.