LCA in Building Certification: Experiences from Germany

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Summary

Life Cycle Assessment (LCA) increasingly gains attention and is used more and more in the building sector throughout the world. Strong support for LCA is given by both International and European standardization activities – e.g. CEN TC 350 (“sustainability of construction works”) defined LCA as the core method to describe the environmental performance of buildings. In addition to standardization, different approaches to assess the sustainability performance of buildings are installed through building certification bodies and some of them include LCA as a mandatory instrument for building assessment.

The German Sustainable Building Council (DGNB) as a non-profit organization to promote sustainable construction was founded in 2007 and subsequently released a sustainability certification scheme for buildings. The life cycle based and performance oriented approach to building assessment is seen as a major feature of the DGNB certification scheme. With an increasing number of certified buildings, the certification yields the rare opportunity to evaluate and compare LCA results for a significant number of different buildings, where the LCAs have been done under the same boundary conditions.

Basis for the comparability of LCA results of certified buildings are consistent and complete definitions to conduct the LCA calculation of the different buildings. On this basis, LCA results evaluated and the results are presented in this work. For the purpose of continued development and improvement of building certification rules, adequate benchmarks and metrics, the results are evaluated and will be statistically analysed in the future. Currently a limited number of datasets for certified buildings is available that allow initial impressions and insights in the LCA results for certified buildings. The findings indicate the appropriateness of the benchmarks currently in place, while it is also indicated that benchmarks may and probably should undergo a development towards tightened values. With increasing numbers of certified buildings in the future, systematic analyses will be possible, yielding a structural understanding of LCAs of buildings, core influencing factors and good benchmark levels.

Keywords: Life Cycle Assessment; LCA; DGNB; German Certification for Sustainable Construction; German Sustainable Building Council; Green Buildings; Building LCA Results

1. Introduction

During the last few years, national Green Building Councils appear on the stage all over the world. They pursue quite different approaches to green buildings. In Germany, the German Sustainable Building Council (“Deutsche Gesellschaft für Nachhaltiges Bauen”, DGNB) was founded in summer

2007; by spring 2011, it holds around 1.000 member organizations. As a means to promote sustainable construction in Germany and throughout the world, the DGNB developed the German Certification for Sustainable Construction (“Deutsches Gütesiegel Nachhaltiges Bauen”). This certification scheme generally covers all aspects of sustainability in the built environment and asks for specific performance levels in individual criteria.

On the basis of a catalogue of approx. 50 of such criteria, an overall sustainability performance of the building is evaluated and a metal color (gold / silver / bronze), as well as a grade is awarded to the building. Each criterion reflects one aspect that is understood to be relevant to sustainability. One criterion thereby has one or several indicators, each quantitative or qualitative and defines the method for the assessment, resp. the calculation method for quantification and benchmarks.[1]

Two prominent methods to perform a life cycle based quantitative assessment are Life Cycle Costing (LCC), accounting for economic aspects and Life Cycle Assessment (LCA) as defined in ISO 14040 [1] and 14044 [2], quantitatively investigating environmental impacts. Both of these methods, which are mandatory parts of a DGNB sustainability assessment, yield a share of 13,5 % (each) on the overall contribution to the sustainability performance of the building [3].

Especially the method of Life Cycle Assessment combines two elements that are seen to be of major relevance, namely the assessment of the entire life cycle of the building and the definition of benchmarks on a performance level, rather than prescribing “good” measures. Both features are in line with the standardization activities of CEN TC 350 “sustainability of construction works”, standardized especially in FprEN 15978 [4].

2. LCA in the certification scheme

1.1. Definitions of LCA for building certification

The Life Cycle Assessment is done for the entire building’s life cycle and follows defined procedures and uses pre-defined boundary conditions and other specifications. An explanation of the use of LCA within the certification scheme is given in [5] and partly repeated here to allow for a convenient overview over the aspects of LCA in building certification.

The outcome of an LCA in general is a quantification of environmental impacts, e.g. using several environmental impact categories (‘midpoint indicators’). Five of such impact categories plus two energy demand indicators are considered within the DGNB system as individual criteria. These are Global Warming Potential (GWP100), Ozone Layer Depletion Potential (ODP), Photochemical Ozone Creation Potential (POCP), Acidification Potential (AP), Eutrophication Potential (EP), Primary Energy (PE) Demand (non-renewable) and Primary Energy Demand (non-ren. + renewable) with the share of renewable energy.

For the building LCA, the entire life cycle, consisting of four major elements has to be taken into account. These elements are the construction phase, necessary refurbishment during the reference service life of 50 years, the building’s end-of-life and the building’s operation during the use phase.

Within the construction phase, simplifying rules on which building components have to be considered are in place, reducing the building’s structure to eight elements such as exterior walls, roof or foundation, as well as the heat generators as a proxy to the building’s technical equipment.

The refurbishment of the building during its use of 50 years considers any necessary material exchange measures. For that purpose, default reference service life values for individual building elements are used to define an exchange frequency for each material, resp. construction element used.

The prediction of the necessary measures to be taken, and of possible improvements of the building’s performance is difficult to make – if at all. To assure comparability of the different buildings, for the use phase scenario, no retrofit-measures that improve the building’s e.g. energy efficiency are considered. Neither are maintenance measures such as cleaning or inspection considered.

The end-of-life is accounted for by means of a ‘standardized’ scenario. A number of different

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[1] General explanations and detailed descriptions oft he DGNB certification scheme are given in [3].

material groups are identified and each group has an individual end-of-life scenario. Examples of such scenarios are incineration with recovery of thermal and electric energy for plastics, wood and other materials that have a calorific value or recycling of stones and bricks to yield recycled aggregates (etc.).

The combination of these three life cycle phases yield the results for the "construction". The operation of the building uses the results of the "Energieausweis", i.e. the calculation results from the German implementation of the European EPBD [6]. Here, final energy values for heat and electric energy are calculated for the building and of a reference building. The energy demand values are multiplied with the LCA datasets of the energy used to assess the environmental impacts of the operation phase. The environmental impacts of the building's life cycle are then normalized to one year and one m² net floor area ("Nettogrundfläche" NGF_a).

1.2. Benchmarking LCA based environmental impacts for certified buildings

The LCA benchmarks for buildings within the DGNB system are set on the level of the entire life cycle of the building. I.e. one overall value has to be met by the building. This procedure (instead of e.g. setting separate benchmarks for the construction of the building and it's operation) leave the greatest possible flexibility to the planner about how to meet the set requirements. Both, a highly energy efficient building (i.e. small energy demand for operation) that yields more environmental impacts in the construction of the building and a less efficient building with less impacts from the construction are possible to meet the requirements.

The benchmarks are compiled from two elements. The first element is a fixed value that refers to the construction of the building. It is derived from a German national research project [7] that evaluated a number of "typical" buildings in order to derive benchmarks on the basis of mean values and an understanding of the relation between a building and its environmental impacts. For this element of the benchmark, values are given in the characteristics documents of each criterion, e.g. 9,4 kg CO_2-Eq./m^2_{NGFa}*a for GWP. The second element is a variable part that is derived from the "Energieausweis". In accordance with the EPBD, each building has a benchmark set for primary energy demand. For the purpose of LCA-benchmarking, the corresponding final energy demand is multiplied with conversion factors (separately for electric and thermal energy) for each indicator. Therefore, the energy demand is separated into electric energy and thermal energy. These factors are also given in the characteristics documents, e.g. for GWP: power demand to be multiplied with 0,71 kg CO_2-Eq./kWh and thermal energy demand to be multiplied with 0,31 kg CO_2-Eq./kWh. These factors stem from the national building products database and reflect the electric energy grid mix, resp. heat generation with a mix of 50 % oil and 50 % natural gas.

The resulting benchmark (called "reference value" = "Referenzwert") for the building's life cycle represents 5 valuation credits out of a range of 1 credit (minimum) to 10 credits (maximum). The reference value is then multiplied with specific factors to yield the benchmarks for 1 credit and for 10 credits. These specific factors are defined individually to reflect the idea of relation between "state of the art", "still acceptable" and "best practice".

3. Review of LCA results

With increasing numbers of certified buildings, the review and revision of the benchmarks becomes possible. In this context, various questions arise:

- Are the benchmark levels appropriate to allow for a distinction of environmentally good, medium and not so well performing buildings?
- Are the benchmark levels appropriate to foster innovation in environmental and energy efficient building design?
- How does the ratio of environmental impacts from the construction, maintenance and end-of-life to the environmental impacts from operational energy demand compare from building to building?
- Can conclusions be drawn concerning parameters that generally influence the LCA results

of certified buildings?

The first evaluation is the comparison of average levels of performance for all of the assessed indicators in relation to the reference value (corresponding to five credits). Fig. 1 visualizes this comparison, giving the deviation of the mean value of all assessed certified buildings from the reference value. – 30 % corresponds to the 10 credit target value (best). From this evaluation it can clearly be seen that the majority of the buildings performs well in the ‘upper’ area of the rating scale for the environmental indicators. This may be due to the fact that early certificates have been mainly attractive to investors / building owners who have a strong interest in energy efficiency of their building. On the other hand, this result may also lead to the conclusion that the benchmark values rather represent ‘average’ buildings and that ‘best practice’ buildings may perform better than the given benchmarks would suggest. It is especially obvious that for Global Warming Potential (GWP), there is a bandwidth of results between the medium and the best benchmark and for the total Primary Energy Demand (in conjunction with a rated share of renewable energy), there is an even stronger variation of results[2]. Hence, except for the energy based indicators and Global Warming Potential that often directly correlates with non-renewable Primary Energy, the indicators’ benchmarks can and should be revised to allow for distinctions of results. Moreover, as long as good rating results can be reached too easily, the certification procedure does not act as an incentive to pursue innovation in building design and construction. This means in turn, more tightened benchmarks will be necessary, if innovation wants to be promoted through the certification system.

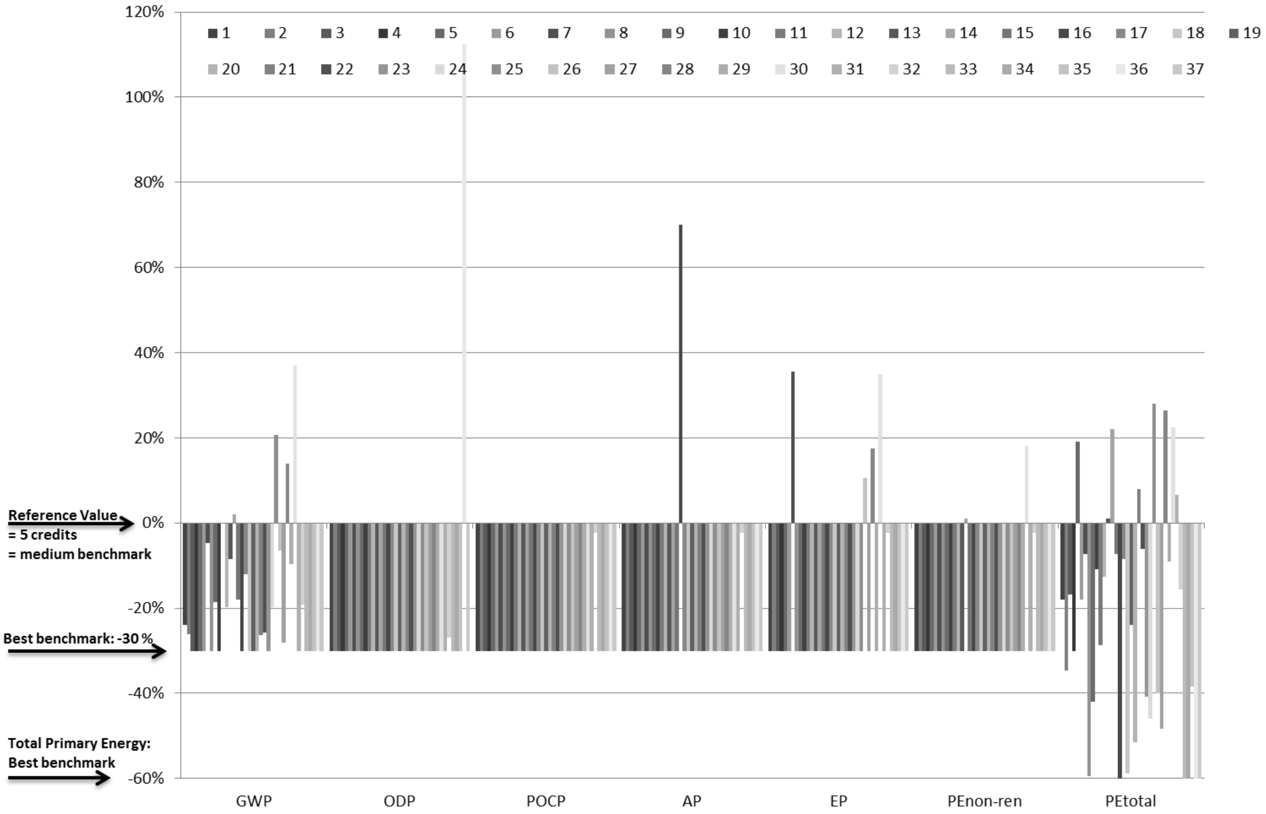

Fig. 1 Deviation of LCA results for different buildings for all indicators from the 5-credit-benchmarks (= 0%)

The metrics for calculating the LCA results for buildings divide the building’s life cycle into the sections “construction”, i.e. the physical building including its construction, maintenance and end-

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[2] Note that for one of several building type certificates, for ODP and POCP, 10 credits are always granted if a calculation is done, without any benchmarking. This may result in the uniform image of mainly best ratings for these indicators.

of-life, and into “operation”, i.e. operational energy demand during the use phase. In addition to that, benchmarks are defined with a uniform value for the “construction” part and a building-specific value for the operational energy demand. Hence, this separation into those two sections is one major feature of the LCA results and requires continued investigation, whether underlying assumptions are valid for certified buildings. Such assumptions are e.g. that the higher variation in calculated LCA impacts lies within the operational energy demand, rather than within the construction section or that for the majority of the buildings, the operation is the dominant section of the life cycle. Fig. 2 through Fig. 5 exemplarily present the results for four of the LCA based sustainability criteria for a sample of certified buildings.

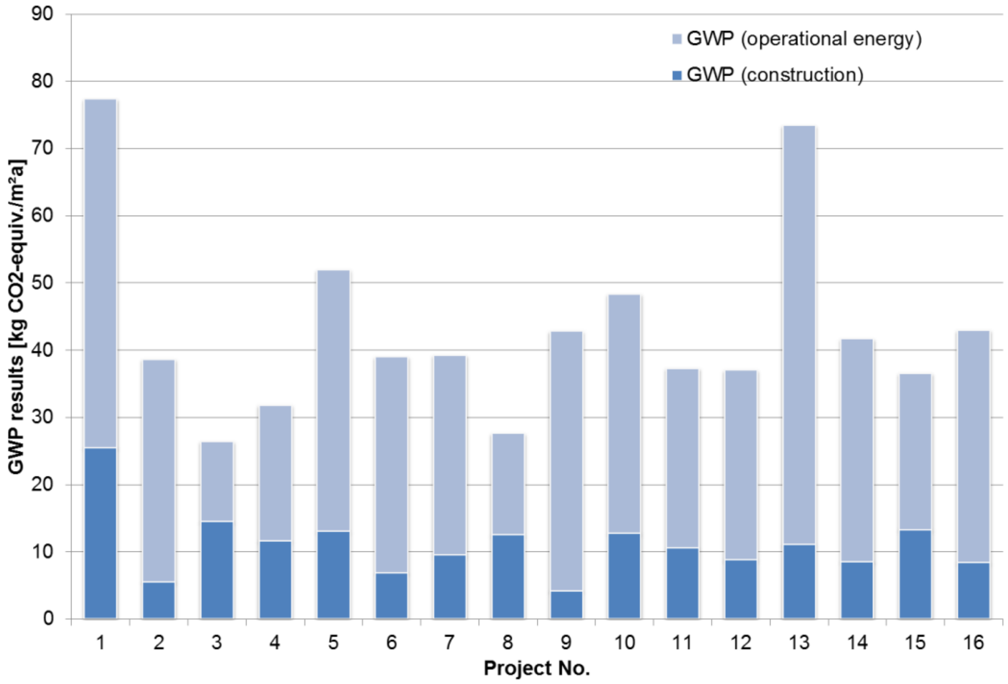

Fig. 2 Global Warming Potential of a sample of certified buildings, divided in impacts from the building construction (incl. maintenance and end-of-life) and impacts from operational energy demand

While the impact category Global Warming Potential (Fig. 2) displays a fairly homogenous distribution of construction to operational energy demand impacts, the impact categories Photochemical Ozone Creation Potential (Fig. 3) and Acidification Potential (Fig. 4) have much stronger variations, in the overall life cycle impacts, as well as within the impacts from construction and those from operational energy demand.

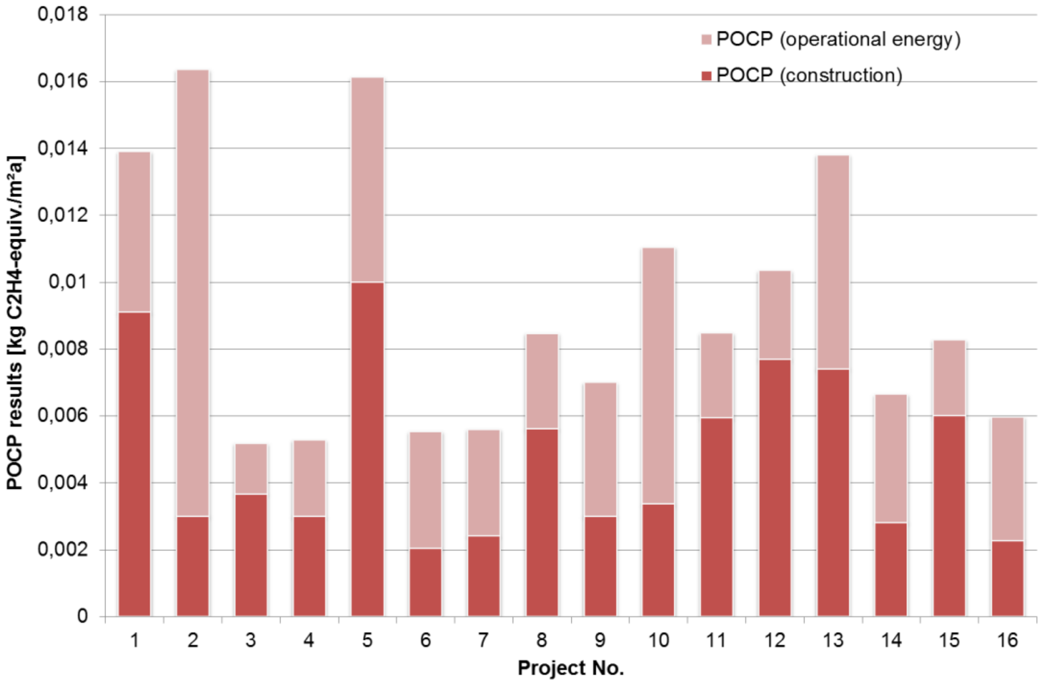

Fig. 3 Photochemical Ozone Creation Potential of a sample of certified buildings, divided in impacts from the building construction (incl. maintenance and end-of-life) and impacts from operational energy demand

The diagrams also indicate that the assumption of the building operation to be the dominant life cycle stage is valid for Primary Energy Demand (Fig. 5) and for Global Warming Potential (Fig. 2) which often correlates with primary energy demand from fossil sources. For Photochemical Ozone Creation Potential (Fig. 3) and Acidification Potential (Fig. 4), again, this is not generally the case. For several of the buildings that have been evaluated, the construction section dominates the life cycle impacts.

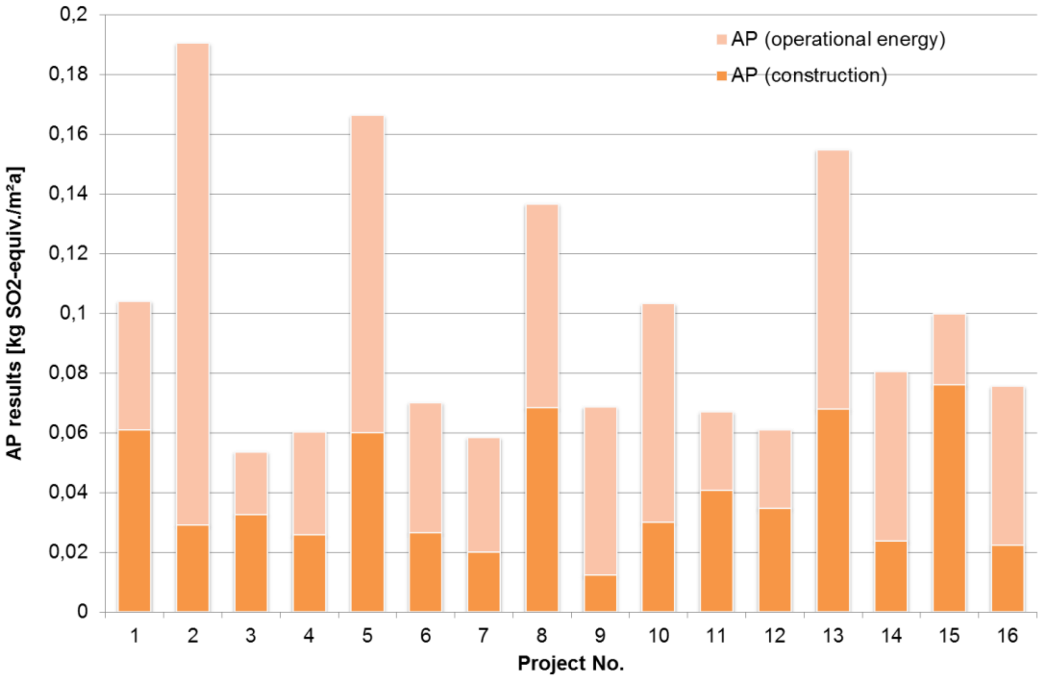

Fig. 4 Acidification Potential of a sample of certified buildings, divided in impacts from the building construction (incl. maintenance and end-of-life) and impacts from operational energy demand

As a consequence, the assumption that both the major impacts and the major variations in impacts within a building's life cycle stem from the operational energy demand, rather than from the building's physical construction should be questioned and possibly revised, if future statistical analyses confirm this initial impression. This could also result in a revision of the procedure to compile the benchmarks from a fixed value for the construction and a building specific value for the operation. Such a revision would also require a thorough and statistically based understanding of the major parameters that influence results within individual impact categories.

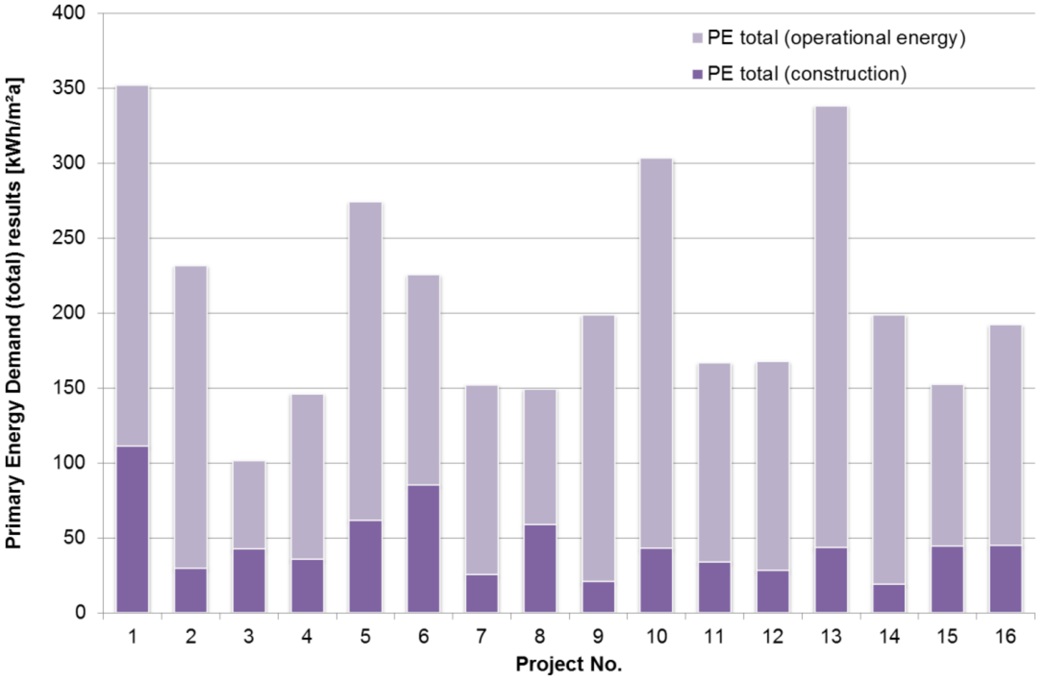

Fig. 5 Primary Energy Demand (non-ren. and ren.) of a sample of certified buildings, divided in impacts from the building construction (incl. maintenance and end-of-life) and impacts from operational energy demand

One question that will become increasingly relevant for the future application of LCA during a building's planning phase is the question of the main influencing parameters for the building's environmental performance. Extensive statistical analyses will be necessary to identify correlations between individual building specifications and environmental impacts / LCA results. One such analysis of possible interest could be that of the correlation of impacts to the overall building's size. Fig. 6 displays the respective analysis: All LCA indicators are displayed against the building's net floor area (German "NGF"), each normalized to the highest value of the sample. This normalization yields a comparability of the indicators to each other, allows a rough comparison of the relation of indicators to each other within one building and finally allows for identifying possible trends of impacts in relation to the building size. Such trends might be a reduction in impacts per square meter if the building turns larger. From Fig. 6, however, no general trend, neither for any single indicator nor for all indicators can be found. This, in turn, could be seen as an indication that the approach of benchmarking per-square-meter-impacts without regard to building size is a valid approach. Future statistical analyses on the basis of large samples should be used to confirm this finding.

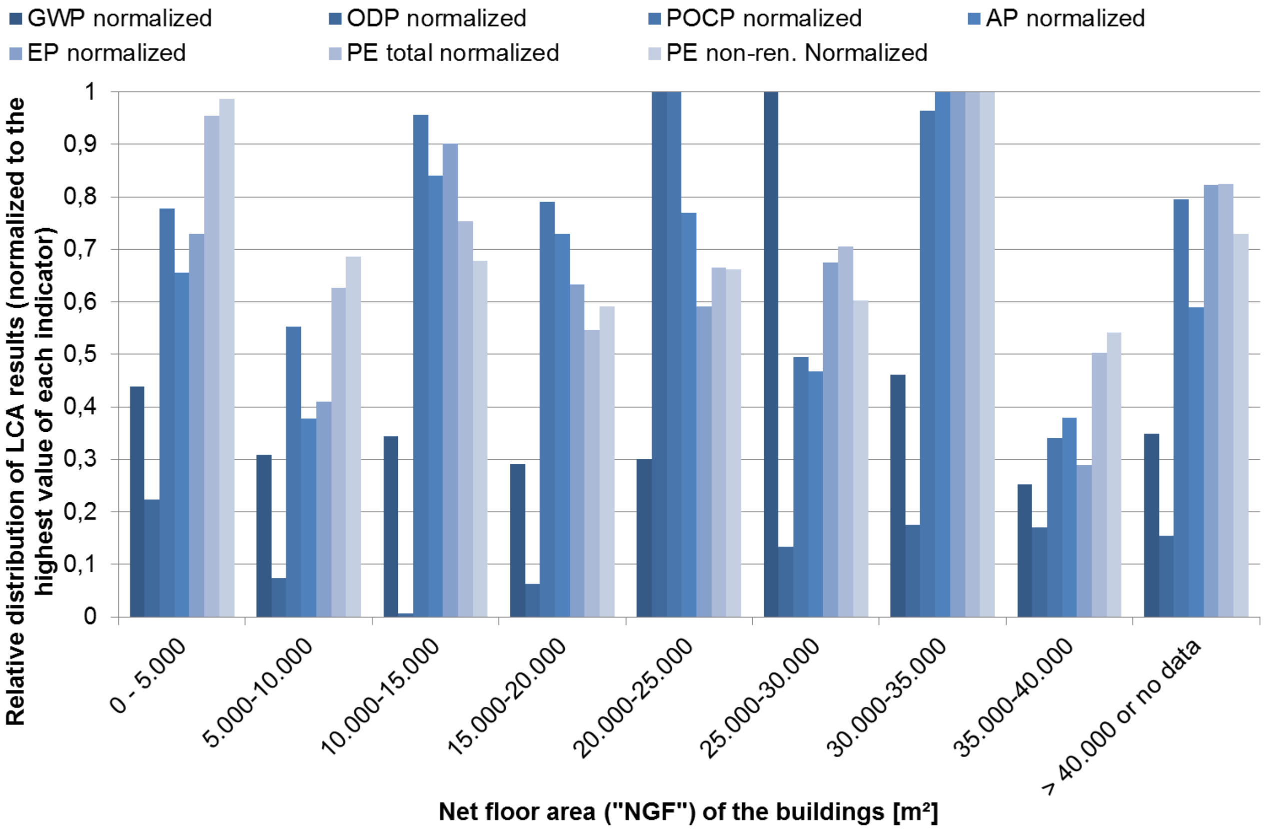

Fig. 6 Normalized LCA results for all indicators. The certified buildings are separated into classes of net floor area ranges (normalization to the highest value of each indicator).

Future analyses should also concentrate on the question, if general patterns of normalized indicator relations (‘how do the normalized indicators behave to each other within one building?’) can be derived. If so, graphs like the one in Fig. 6 could be used to assess individual building results for quick checks of plausibility, e.g. during the inspection of confirmation procedure to assure correctness of the calculations. This would be desirable to improve confidence in LCA results and promote a better understanding of LCA based environmental impacts with planners.

4. Summary and conclusions

Life Cycle Assessment has been established within the German sustainable building certification system and is today generally accepted as a means to assess a sustainable building’s environmental performance. Education of auditors, clearly defined metrics and benchmarks on moderate levels supported this process.

With the first certified buildings evaluated for their LCA results, some general findings have been concluded and require statistical confirmation in the future. These general findings include:

- Benchmarks for LCA indicators are set on a level that allows the distinction of different levels of quality of buildings (for some indicators such as GWP and Primary Energy Demand), while for some indicators, the benchmark levels are set very moderately so that good ratings can be reached fairly easily. This allows for a tightening of benchmarks in the future.
- General assumptions on the relation of the building’s construction to the building’s operational energy demand and the dominance of the operation phase have shown to be valid for some indicators, while for other indicators this is not necessarily the case. After further statistical evaluations, this might yield in future revisions of the benchmark metrics.

- General correlations of environmental impacts to building parameters – beyond the obvious – are yet to be found. Environmental impacts generally do not correlate e.g. to the building size.

In general, Life Cycle Assessment of buildings on a standardized basis – e.g. for the use in a certification system – is still a fairly new field of activity, both for planners and for LCA specialists and should be subject to future research and to continued maturing of the method, the metrics and supporting tools. It does, however, give a transparent insight into the building's environmental performance and is hence an adequate approach to be included into building certification. Especially increased statistical evaluations will be required to deepen the understanding of LCA and to gain statistical proof for several basic assumptions or to revise the approach. The German DGNB sustainable building certification is the first framework, under which consistent LCA studies of buildings are done on a broad level and hence acts as a pioneer to bring life cycle based environmental assessments into the building and construction sector.

5. References

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