LIFE CYCLE-BASED ASSESSMENT OF BUILDINGS

AN ANALYSIS OF 28 RESIDENTIAL BUILDINGS WITH REGARD TO CLIMATE IMPACT AND COSTS IN GERMANY

CONTENTS

SHORT STUDY

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Life cycle-based assessment of buildings: An analysis of 28 residential buildings with regard to climate impact and costs in Germany

Translated from the German original 'Lebenszyklusbasierte Betrachtung von Gebäuden: Eine Analyse von 28 Wohngebäuden zu Klimawirkungen und Kosten'

Summary

With the implementation of the EU's Energy Performance of Buildings Directive (EPBD – 2024/1275/EU), assessment of the life cycle Global Warming Potential (GWP) will become mandatory for large new buildings (useful floor area >1,000m²) from 2028 at the latest, and for all new buildings as of 2030. In preparation for this, the German Sustainable Building Council (DGNB e.V.) together with BPIE (Buildings Performance Institute Europe) examined the general conditions and costs of conducting building life cycle assessments (LCAs) as part of a short study published in April 2025 entitled *Building life cycle assessments: market research on costs and capacities in Germany*.[1] Following on from that study, this short study now provides answers to the question of what additional expenses or cost savings clients can expect when carrying out life cycle-optimised, more climate-friendly residential building projects. To this end, LCA data was analysed for 28 DGNB-certified new residential buildings in Germany with regard to construction costs and CO_2 emissions[2] over the buildings' life cycle.

The evaluation shows that there is no clear negative or positive correlation between the attainment of limit values for life cycle greenhouse gas (GHG) emissions and construction costs. Although, at €220/m²GFA (gross floor area),[3] average life cycle-optimised buildings are marginally more expensive for the evaluated projects, an analysis of individual projects shows that currently, realising life cycle-optimised construction can already be much less expensive than average construction costs. Furthermore, an evaluation of the data shows no correlation between low CO_2 values during building use and high construction costs; the construction costs for buildings with lower GHG emissions in use can also be lower. It should be emphasised that the material qualities of the support structure represent the greatest lever for reducing embodied emissions.[4] If costs are considered not only for construction, but over the entire life cycle, operation costs become increasingly relevant. For every square metre built, almost the same amount of money has to be allowed for and set aside for operation costs over a building's useful life as for its construction.

This study shows that greater climate protection can be achieved at the same cost. In light of this, DGNB and BPIE recommend that all market stakeholders adopt a life cycle perspective on buildings as an opportunity to be seized – both to achieve climate goals and to ensure economic sustainability. Introducing mandatory limit values for life cycle emissions of buildings (also referred to as whole life carbon regulation) in the near future, at least before the EPBD timeline requires it, would provide

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[1] BPIE/DGNB 2025: Building life cycle assessments: market research on costs and capacities in Germany.
[2] In this study the term CO_2 is used to refer to all greenhouse gases.
[3] Gross floor area; in German *Bruttogrundfläche im Regelfall* (BGF(R)) as per DIN 277
[4] In German also referred to as grey emissions

guidance from policymakers for the German market. To obtain the necessary information, unbureaucratic and targeted procedures could be established based on the ever-growing availability of LCA consultants and life cycle assessment tools.

Background

The importance of the building sector for achieving climate goals has become the focus of decisions and activities among both policymakers and the majority of building sector stakeholders. While past efforts were heavily directed at improving energy efficiency in building operations, in other words, saving energy when heating and cooling, the perspective has increasingly shifted to a life cycle approach. This approach means that the way in which buildings are constructed or renovated, how products and materials are manufactured and transported, and what happens to them after use are also taken into account in the decision-making process.

The role of building LCAs in adopting a life cycle perspective

A building LCA, sometimes also referred to as an environmental LCA, is a systematic analysis of the environmental impact of a building over its entire life cycle.[5] This involves determining both emissions and resource consumption associated with a building (embodied emissions), as well as emissions and resource consumption caused by using a building over its lifetime (operational emissions). The procedure has been standardised for many years: in Germany, DIN EN 15978 serves as the key standard for building LCAs, while DIN EN 15804 defines the underlying data for products and processes.[6] Building LCAs help to identify the building components or life cycle phases with the greatest environmental impact (so-called hot-spot analysis) and identify potential for improvement by comparing different variants. The results can also be compared with limit values or reference values.[7] The short study on 'Building life cycle assessments: market data concerning relevance and costs in Germany'[8] provides information on the factors that determine the quality of a building LCA.

Building LCAs and life cycle limit values are being introduced via EU regulations

The life cycle perspective has also found its way into the EU regulatory framework. With the new version of the EPBD issued in May 2024, the disclosure of life cycle GHG emissions for new buildings will be required from 2028. Member states are also required to develop national roadmaps in which it is outlined how limit values for the life cycle global warming potential (GWP) will be introduced from 2030 onwards such that they follow a steady downward trend and are in line with EU carbon neutrality targets. The EU Taxonomy Regulation, which defines environmentally sustainable economic activities, and the announced

[5] For further information, see, for example, DGNB 2018: Leitfaden zum Einsatz der Ökobilanzierung (Guide to the use of life cycle assessment (German)).
[6] DIN EN 15978: Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method; DIN EN 15804 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products.
[7] For example, to demonstrate funding or financing criteria, in the context of certifications or – as already introduced in some European countries – for building approvals.
[8] BPIE/DGNB 2025: Building life cycle assessments: market research on costs and capacities in Germany.

requirements for the green public procurement of buildings also call for the disclosure and limitation of life cycle GHG emissions.

The environmental information required for building LCAs is currently provided voluntarily by many manufacturing companies in a structured and verified form by means of Environmental Product Declarations (EPDs). Under the new version of the Construction Products Regulation (CPR (EU) 2024/3110), the provision of environmental information will be mandatory for the standardised product categories.[9]

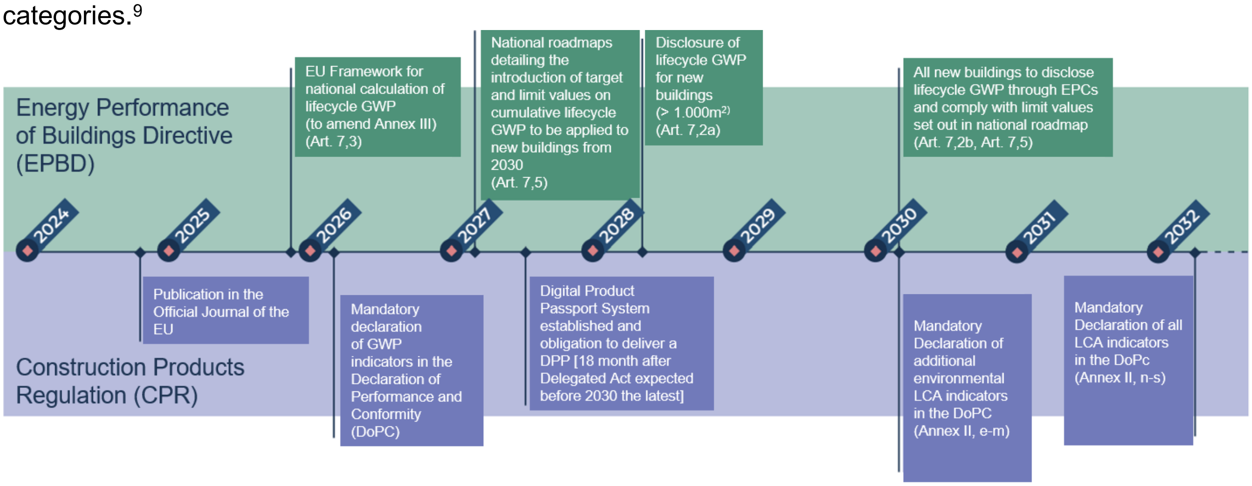

Figure 1: Overview of the timetable for the Energy Performance of Buildings Directive (EPBD) and Construction Products Regulation (CPR). Source: translated and updated from BPIE 2024[10]

Building LCAs are being tried out in Germany, but are not yet established in regulatory law

In Germany, it has been possible to calculate building LCAs for around 20 years. The first Ökobaudat database established for this purpose was published in 2006 and, from the time of their launch in 2008, this enabled the first certification systems for buildings (DGNB and BNB) to provide reference and target values. Since 2022, in order to receive state subsidies under the 'Climate-friendly New Buildings' funding programme, proof of a building LCA must be provided confirming that a building meets required limit values of life cycle GHG emissions. In Germany, introducing such life cycle GHG limit values into regulatory law has so far only been announced, discussed and subjected to preparatory evaluation as part of research projects since 2019.[11]

[9] BPIE 2024: How to establish WLC benchmarks? Insights and lessons learned from emerging approaches in Ireland, Czechia and Spain
[10] BPIE 2024: How to establish WLC benchmarks? Insights and lessons learned from emerging approaches in Ireland, Czechia and Spain
[11] BBSR 2019: Mögliche Optionen für eine Berücksichtigung von grauer Energie im Ordnungsrecht oder im Bereich der Förderung. Endbericht (Possible options for considering grey energy in regulatory law or in the context of funding. Final report (German)); BMWSB/BMWK 2023: Gemeinsamer Bericht über Forschungsergebnisse zu Methodiken zur ökobilanziellen Bewertung von Wohn- und Nichtwohngebäuden (Joint report on research results on methodologies for the life cycle assessment of residential and non-residential buildings (German)). Publication 20/8830; BBSR 2024: Klimafreundliche Wohnbauten. Erprobung und Weiterentwicklung von Grundlagen der Ökobilanzierung (Climate-friendly residential buildings. Testing and further development of life cycle assessment principles (German)).

By contrast, a steadily growing number of European countries have already established life cycle regulation for buildings in national law: France, Denmark and the Netherlands have set limits for global warming potential per square metre of newbuilds as a basis for approval, while Sweden, Norway, Finland, Iceland and Estonia have made the disclosure of building LCA results mandatory. Other countries, such as Spain and Ireland, are preparing steps for implementation.[12] Germany is also being called upon to use the planned implementation of the EPBD to make more ambitious progress and regain its former pioneering role in life cycle-optimised construction.[13] Limit values would then apply to all new buildings – not from 2030 onwards, as envisaged in the EPBD in the national roadmaps, but sooner.

The countries that are leading the field in this respect show that introducing limit values is usually a gentle process. According to a preliminary study, in Denmark few buildings had difficulties complying with a first life cycle limit value because it was easy to satisfy with good building practice. This has enabled the market to prepare and adapt. It was not until two years later that the Danish limit value was lowered further. Learning from this experience, it is also recommended that Germany start with an ‘achievable’ initial value when introducing a limit, which can then be gradually lowered.

Aim of the background paper and methodological approach

Some construction project clients and planners are concerned that complying with life cycle limit values – in other words having to apply life cycle-optimised construction methods – could drive up construction costs further. The aim of this short study is therefore to offer evidence for the debate on climate impacts, costs and the opportunities of life cycle-optimised construction. To this end, building LCAs and the life cycle costs of 28 DGNB-certified new residential buildings were analysed. The key questions to be answered were: Do requirements to reduce life cycle CO_2 emissions increase construction costs for clients? And if so, by how much?

To answer these questions, the results of two certification criteria of the German DGNB System were analysed in detail: Life cycle costs (ECO1.1) and Building life cycle assessment (ENV1.1). The results were also compared with overall sustainability evaluations (the DGNB ‘total performance index’).

[12] BPIE 2024: How to establish WLC benchmarks? Insights and lessons learned from emerging approaches in Ireland, Czechia and Spain; Nordics Co-operation 2024: Harmonised Carbon Limit Values for Buildings in Nordic Countries: Analysis of the Different Regulatory Needs.

[13] BPIE 2023: Regulierung der Lebenszyklus-THG-Emissionen von Gebäuden – Empfehlungen für Deutschland (Regulation of life cycle GHG emissions from buildings – recommendations for Germany (German)); requirements paper "Nachhaltiges Bauen und Lebenszyklusbetrachtung stärken (Strengthening sustainable building and life cycle assessment (German))" DGNB and other associations (2024).

Characteristics	Underlying data used
Analysed buildings	28 new residential buildings with more than six residential units
Building size	700 m² – 25,000 m² GFA
Applied LCA and life cycle costing methods	According to the DGNB Certification System for New Construction, Residential Buildings, 2015 version and 2018 version
Year of building completion	From 2016 to 2023

Table 1: Underlying data used in the short study

For the evaluation, the GHG emissions of buildings were correlated with the construction costs of the German standard DIN 276 cost groups KG 300 and KG 400. Collected data was sorted and plotted in four boxes in the charts below. Sorting is based on the reference values for construction costs and GHG emissions in Table 2.

Analysed parameters	Selected reference values
Construction costs, gross, costs as of Q1/2024	€1,800/m²GFA
GHG value for the product stage (modules A1-A3)	8.4 kg CO_2e/m²NFA[14]*a
GHG value of the building (modules A1-A3, B4, C3, C4)	10 kg CO_2e/m²NFA*a

Table 2: Reference values used for GHG values and costs

Regarding the choice of reference values for costs, the value for constructing a residential building was determined in keeping with both the German fm.benchmarking report 2023[15] and the German Federal Statistical Office (Destatis) 2022[16]. According to the latter, the construction costs[17] for residential buildings with three or more dwellings are approximately €2,650 per square metre of living space. Taking a typical ratio of GFA to living space of 1 to 0.7, this results in construction costs of €1,850/m²GFA. According to the fm.benchmarking report 2023, construction costs based on gross Q1/2024 values amount to approximately €1,600/m²GFA. The construction costs of all evaluated projects were averaged to the same price level[18]. To do this, construction costs were brought to the same cost level using the construction price index[19]. For comparability purposes, the construction costs are based on GFA.

[14] equivalent to *Nettoraumfläche im Regelfall* (NRF(R)) as per DIN 277
[15] German Chamber of Industry and Commerce 2023: Benchmarking Report 2023: Performance analysis and best practices.
[16] Federal Statistical Office (Destatis) 2022: Baugenehmigungen und Baukosten 2021 (Building approvals and construction costs 2021 (German)).
[17] Cost level Q1/2024 adjusted, gross
[18] Cost level Q1/2024, gross
[19] Destatis: Preisindizes für Bauwerke, Wohngebäude und Nichtwohngebäude (Price indices for construction work, residential buildings and non-residential buildings (German))

Regarding the choice of reference values for GHG emissions, the boundary between lower and higher GHG emissions was also determined on the basis of classification values. To be classified as a building with 'lower GHG emissions' within the context of this study, the GHG value calculated for the product stage of a building[20] had to fall below 8.4 kg CO_2e/m^2NFA*a;[21] for a building over its life cycle[22] it had to fall below 10 kg CO_2e/m^2NFA*a.[23] The areas to which GHG emissions related were defined throughout this study as the net floor area, or NFA. Product stage values for a building are based on DGNB System 2023, while the second reference value for a building over its life cycle is derived from a study carried out in 2022, on which QNG (Quality Seal for buildings) eligibility criteria are based. The GHG value is also referred to below as global warming potential (GWP) with an indication of the life cycle modules it contains.

Results of the analysis of the costs of life cycle-optimised construction

The results of the analysis are presented below from various perspectives. Correlations are shown, on the one hand, between building emissions and building use emissions, and on the other, the construction costs. Emissions and costs are considered over the entire life cycle and the impact of the chosen structural design is shown on building-related emissions. Also, the correlation between construction costs and sustainability evaluations according to the DGNB Certification System is analysed.

Correlation between building-related emissions and construction costs

Life cycle-optimised construction methods are not necessarily more expensive to implement. Currently, compliance with life cycle GHG limit values can be achieved with significantly lower construction costs.

Of the 28 projects analysed, 21 were better than the reference product stage value of the building (8.4 kg CO_2e/m^2NFA*a). Two thirds of these projects were slightly or significantly more expensive than the mean construction cost. However, one third were realised for considerably less than this mean cost, with the least expensive project costing approximately €1,100/m^2GFA. Although the three timber construction projects (marked in orange) all exceed the mean cost, two of those fall slightly higher, i.e. below €2,000/m^2GFA. One of those projects returned a negative CO_2 balance for the product stage of the building.

[20] Modules A1-A3
[21] DGNB 2023: Criteria Set for New Construction Buildings, Version 2023.
[22] Modules A1-A3, B4, C3, C4
[23] König & Hafner 2022: RV Handlungsplan Nachhaltiges Bauen: Entwicklung von LCA-Benchmarks bei Wohngebäuden (Framework agreement – action plan for sustainable building: development of LCA benchmarks for residential buildings (German)).

Overall, the evaluation shows that when the construction costs of a building comply with the GWP reference values for the product stage of a building (modules A1-A3) (larger green dot), they are only marginally higher than the mean construction costs of all projects (larger grey dot).

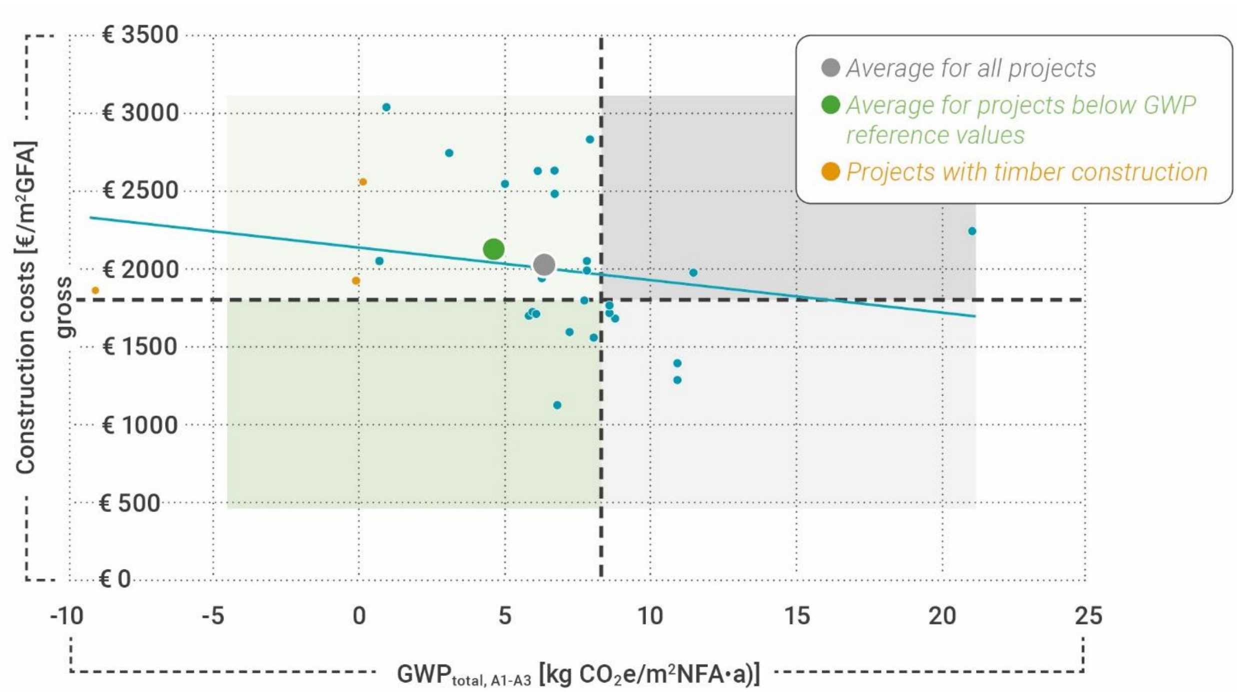

Figure 2: Correlation between CO_2 emissions for the product stage of the building and construction costs

Even considering the entire building over its life cycle, i.e. including replacement, waste treatment and disposal, the life cycle GHG reference value can be achieved 'less expensively' but also 'more expensively'.

Eleven projects[24] were assessed by considering building-related GHG emissions over the life cycle – i.e. including scenarios for emissions caused by replacing building materials over the life cycle, by waste processing and by disposal (B4, C3, C4). Also with these projects, it was found that there are both 'less expensive' and 'more expensive' buildings. The appendix contains a further chart showing all 28 projects and the correlation between total GWP and construction costs.

[24] The analysis of GWP values for the life cycle of the construction works (Figure 3, Figure 6) could only be carried out on the basis of data from 11 projects. This is because the other 17 projects were certified according to earlier DGNB versions (before version 2023), in which modules C and D were considered together in the LCA. Calculation and conversion without module D was not possible for this publication.

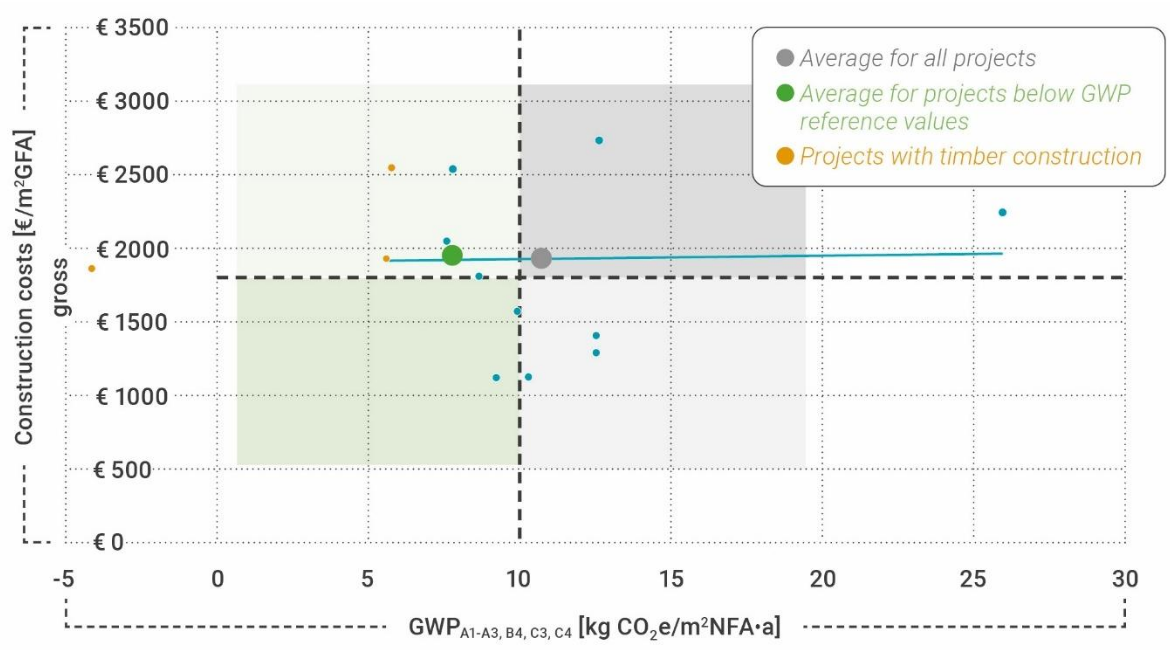

Figure 3: Correlation between CO_2 emissions over the life cycle of buildings and construction costs

The analyses in Figures 2 and 3 reveal both inexpensive residential buildings with lower life cycle GHG emissions and expensive residential buildings with low life cycle GHG emissions. Furthermore, buildings above the reference values for GHG emissions are both above and below the value set for construction costs.

Correlation between operating emissions and construction costs

Low CO_2 values for residential buildings in use are not always associated with higher construction costs.

To analyse the entire life cycle of a residential building, it is also necessary to consider CO_2 emissions in use. Low GWP values in use (module B6) are often associated with high construction costs because the building envelope and technical building services have to meet higher efficiency requirements. To examine this, GHG emissions linked to operational energy (module B6, excluding electricity for user equipment) were compared with the construction costs [€/m²GFA]. To classify values for the GHG emissions of operation excluding electricity for user equipment[25], 10 kg CO_2e/m²NFA*a for the building over its life cycle[26] and 10.5 kg CO_2e/m²NFA*a calculated for electricity for user equipment could be deducted from the limit value for QNG-Plus for the entire building (24 kg CO_2e/m²NFA*a[27]). According to the rules of the QNG sustainable building quality seal[28], user electricity can be set at approx. 10.5 kg CO_2e/m²NFA*a. This value is based on the QNG user electricity flat rate for residential buildings (20 kg CO_2e/m²NFA*a) multiplied by the national grid electricity mix.

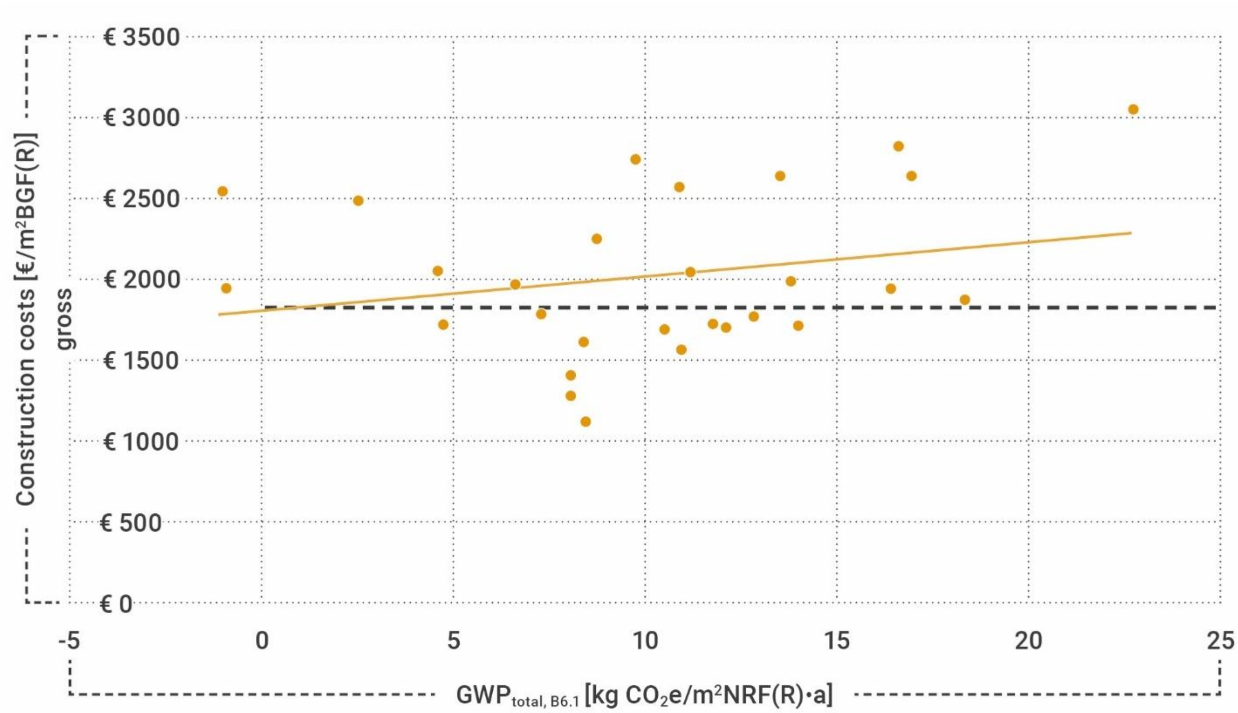

Figure 4: Correlation between CO_2 emissions for building use and construction costs

[25] Module B6.1
[26] Modules A1-A3, B4, C3, C4
[27] See: Manual for the QNG sustainable building quality seal – Annex 3. As of 19/07/2024
[28] See: Annex 3.1.1 LCA accounting rules for residential buildings. As of 19/07/2024

The evaluation shows that buildings with low GHG emissions in use are achieved with both low and high construction costs (in relation to m²GFA). The argument that low CO_2 values during use are associated with high construction costs is thus not confirmed. The line on the graph shows a slight opposite dependency: buildings with lower GHG emissions in use often have lower construction costs, while buildings with higher GHG emissions in use are also associated with higher construction costs.

Low CO_2 emissions during building use correlate with higher costs for technical installations (KG 400) as a share of total construction costs.

If only the construction costs of cost group 400 (KG 400, Building - Technical Systems) are considered in relation to CO_2 emissions during building use, the trend line on the graph shows that low emissions in use are not necessarily associated with higher construction costs. In fact, lower construction costs correlate with low CO_2 emissions. The 28 projects have average construction costs for KG 400 of approx. €450/m²GFA. However, if the percentage of KG 400 costs is considered as a share of total construction costs, it becomes apparent that the share of costs for technical systems (KG 400) within the building's total construction costs increases as CO_2 emissions during use decrease. The share of construction costs averages around 23%, with shares of KG 400 varying between 13% and 34%.

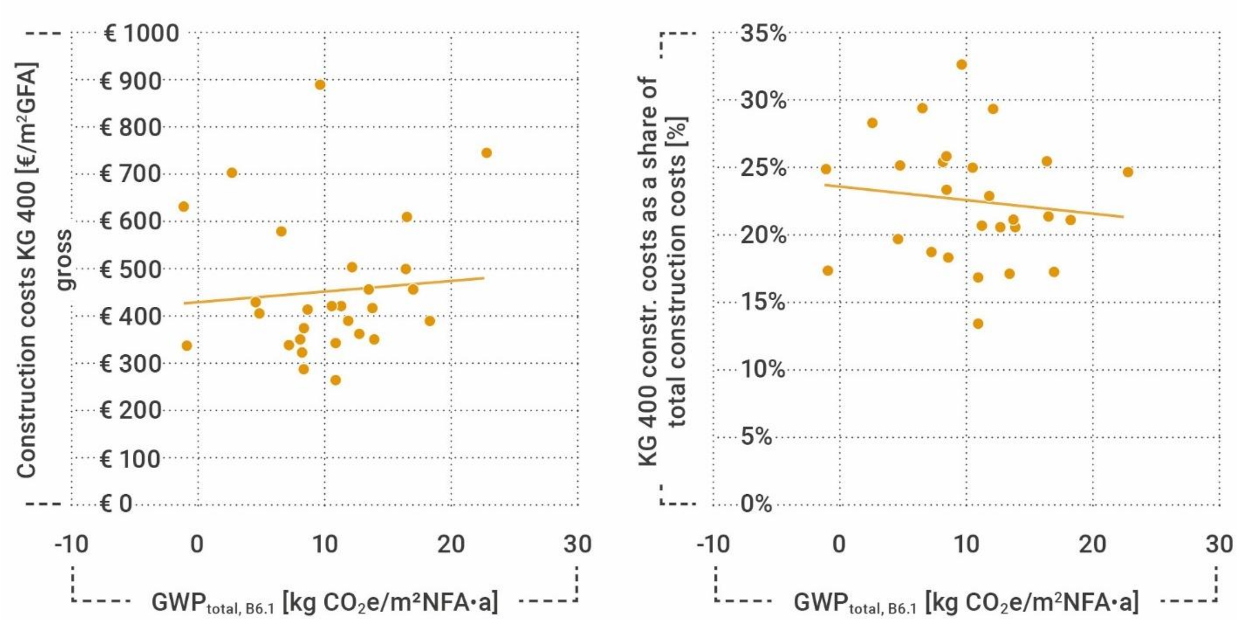

Figure 5: Correlation between CO_2 emissions during building use and KG 400 construction costs, and KG 400 construction costs as a share of total construction costs

Analysis of emissions and costs over the entire life cycle

Buildings optimised over their entire life cycle can be realised at similar costs to conventionally constructed buildings.

When comparing construction costs (KG 400) with GHG emissions over the entire life cycle, there is a noticeable tendency for buildings with lower CO_2 emissions to have slightly higher construction costs (see Figure 6). Average construction costs are €1,930/m²GFA, which is €130/m²GFA above the reference value of €1,800/m²GFA.

To classify GHG values, the share of user and use-related energy consumption (module B6.3) of 10.5 kg CO_2e/m²NFA*a can be deducted from the limit value for QNG-Plus for the entire building (24 kg CO_2e/m²NFA*a), resulting in an applicable reference value of 13.5 kg CO_2e/m²NFA*a. The average value of GHG emissions over the entire life cycle (modules A1-A3, B4, B6.1, C3, C4) of the 11 projects[29] is 13.6 kg CO_2e/m²NFA*a, and thus almost equal to the reference value of 13.5 kg CO_2e/m²NFA*a.

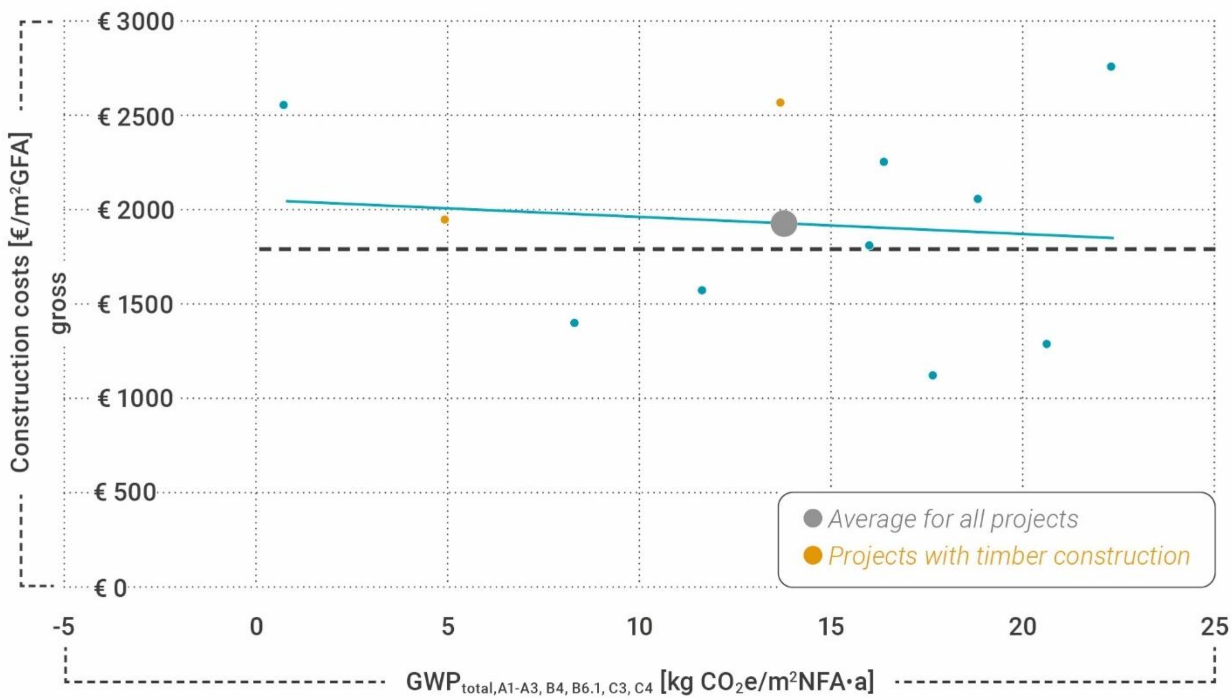

Figure 6: Correlation between CO_2 emissions over the entire life cycle and construction costs

[29] See note to Figure 3 concerning the data set

An assessment of life cycle costs shows that changing circumstances quickly focus attention on costs during building use.

Life cycle costs are those incurred over the 50-year reference service life of a building, i.e. construction costs including the cost of using a building. A life cycle cost (LCC) analysis is used to make long-term financial decisions. The 28 residential buildings were also analysed with regard to life cycle costs. For the evaluation, a distinction was made between the method applied under the 2015 version of the DGNB System for New Construction of Buildings[30] and the method applied under the 2018 version of the DGNB System for New Construction of Buildings[31]. Fifteen residential buildings were certified with the 2018 DGNB System and thirteen residential buildings with the 2015 DGNB System. It is important to take into account the different parameters and assessment frameworks of the two DGNB systems and the resulting lack of comparability of values. The two versions are based on different assumptions regarding cost trends. In the 2015 version, the costs of water and wastewater assume price increases of 3% (2018 version: 2%), energy costs increasing by 4% (2018 version: 5%) and a calculated interest rate of 5.5% (2018 version: 3%).

Calculating life cycle costs makes it possible to calculate the comparative costs of buildings with similar uses and functions. Life cycle costs are calculated using the net present value method[32] over a reference period of 50 years. The construction costs include cost groups 300 and 400, i.e. the construction of the structure and the technical installations of a building. In addition to supply and disposal costs (water, combustibles, energy and wastewater), operation costs also include the cleaning and maintenance of buildings, inspection and maintenance of the structure and technical installations, and repair of the building structure and technical installations. Life cycle costs are defined in net as €/m²GFA. Construction costs were determined on the same cost basis (Q1/2024), while the basis of operation costs varies depending on the date of registration of the certificate (DGNB System 2015): Q3/2016 – Q4/2020, DGNB System 2018: Q1/2019 – Q4/2024).

[30] DGNB 2015: Criteria Set for New Construction Buildings, Version 2015.
[31] DGNB 2018: Criteria Set for New Construction Buildings, Version 2018.
[32] The net present value method is an investment calculation method that determines the value of a project or investment in the present.

Figure 7 shows the shares of construction costs and operation costs for DGNB System 2015 and DGNB System 2018. This shows that the construction costs as a share of the total life cycle costs of the projects under DGNB System 2018 are lower than with the projects under DGNB System 2015. While the absolute values of the construction costs (DGNB System 2015: €1,753/m²GFA, DGNB System 2018: €1,651/m²GFA) remain virtually the same, operating costs (DGNB System 2015: €754/m²GFA, DGNB System 2018: €1,412/m²GFA) rise sharply according to the net present value method. Due to the changed parameters, it is clear that not only construction costs play a role, but also the operation costs become noticeably more relevant.

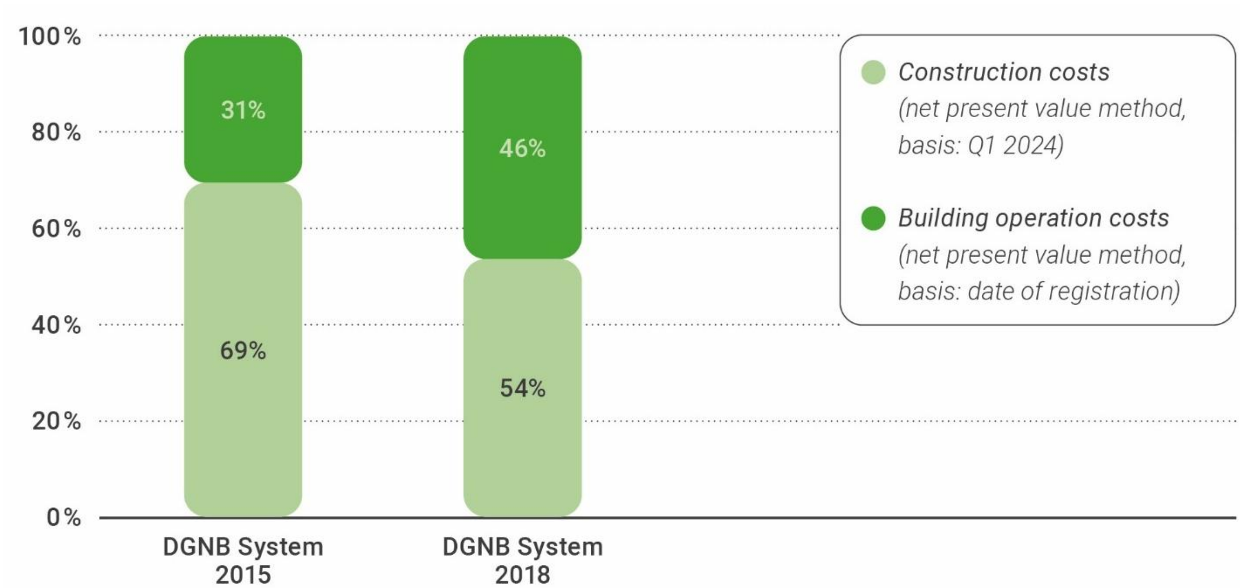

Figure 7: Construction costs and operation costs as a share of the total costs of certified residential buildings (net present value method)

While total life cycle GHG emissions fall significantly the more energy-efficient a building is, the share of building-related GHG emissions rises moderately

Figure 8 breaks down the shares of GHG emissions of buildings over the life cycle (modules A1-3, B4, C3, C4, D) and of their operation (B6.1) for the 28 residential buildings according to the two DGNB systems: Construction of New Buildings, Version 2015 and Construction of New Buildings, Version 2018. It can be seen that the total life cycle GHG emissions of the newer certified residential buildings (DGNB System 2018) of 15.4 kg CO_2e/m²NFA*a are significantly lower than those of the residential buildings certified according to DGNB System 2015, which are 21.8 kg CO_2e/m²NFA*a. Total GHG emissions are reduced by 30%. At the same time, the share of building emissions as a percentage of total emissions rises from 34% to 57%. In particular, GHG emissions from operation (module B6.1) are reduced. One reason for this is that, in addition to the increased share of renewable energies in electricity and heat generation[33], the final energy demand of residential buildings also falls by around 25%. Figure 10 shows that better energy performance and slightly higher building-related emissions can be observed in the projects analysed according to the DGNB System 2018.

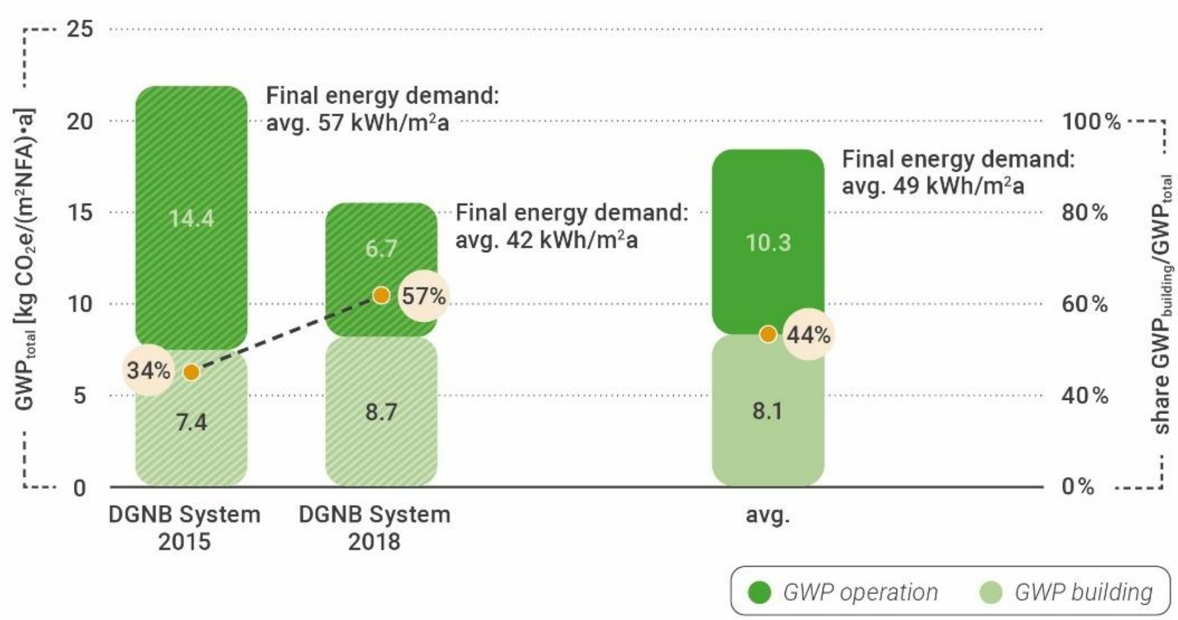

Figure 8: Average GWP values split into GWP of building use and GWP of the building, showing final energy demand of the 28 certified residential buildings

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[33] Umweltbundesamt (German Environment Agency) "Renewable energies in figures" (website)

Figure 9 shows the shares of the individual residential buildings certified under DGNB System 2018 that were included in the analysis, sorted by operating emissions in descending order. Buildings certified under DGNB System 2015 are shown as an average. It can be seen that with higher energy efficiency, i.e. lower operating emissions (dark green), the share of building-related emissions (light green) increases. Residential buildings certified under DGNB System 2018 have an average GWP value for the building and building use of 15.4 kg CO_2e/m²NFA*a.

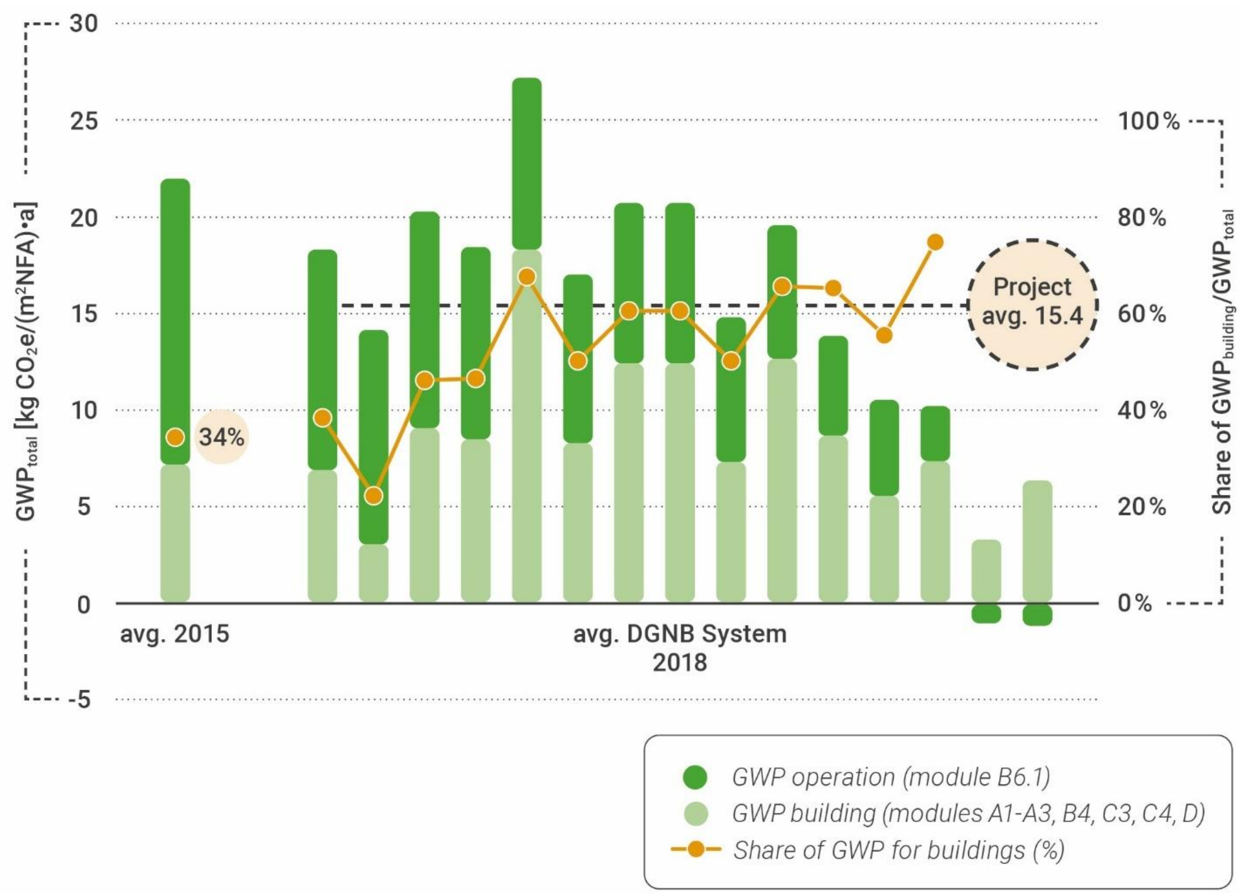

Figure 9: GWP values for buildings and operation showing grey emissions as a share of total emissions

Building-related emissions depending on the construction method of the structural framework

Construction methods and the materials used for the structural framework of a building offer planners the greatest leverage for reducing building-related greenhouse gas emissions.

The analysed projects can be divided into three construction methods: timber, timber-hybrid and solid-wall construction. Figure 10 shows the GWP values for a building over its life cycle (modules A1-A3, B4, C, D) and, separately, GWP values for the product stage of a building only (modules A1-A3) in ascending order.

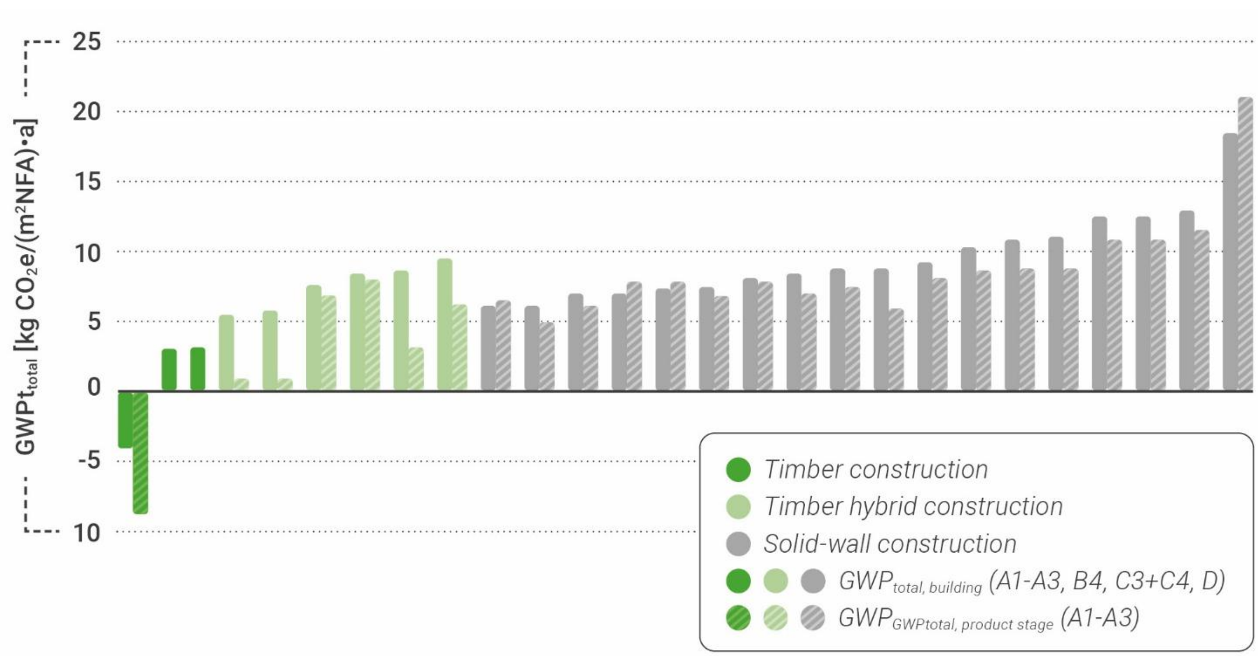

Figure 10: CO_2 emissions over the life cycle of a building and for the product stage of a building depending on the construction method of the structural framework

A correlation clearly exists between the material and construction method of the structure and GHG emissions of the product stage of the building. Buildings with a timber structure have the lowest emission values. The GWP values for the product stage of a building (modules A1-A3) are in some cases higher than the GWP values for the life cycle of the building (modules A1-A3, B4, C3, C4, D). This is because with some projects, module D is entered as a negative credit in the CO_2 balance if the benefits (e.g. resources saved or credits from energy exports) outweigh the additional environmental impacts of modules B4 or C.

Figure 11 shows the distribution of GHG emission values for buildings over the life cycle of all 28 projects. A broad spread of values can be seen. The lowest value is negative at -4 kg CO_2e/m²NFA*a, while the highest value is 18.4 kg CO_2e/m²NFA*a. If these two outliers are disregarded, the results are distributed as follows: a quarter of the projects cause GHG emissions for the building in a range of 3 to 6.3 kg CO_2e/m²NFA*a, a quarter of the projects are between 10 and 12.9 kg CO_2e/m²NFA*a and half of the projects cause GHG emissions between 6.3 and 10 kg CO_2e/m²NFA*a. The average value across all 28 projects is 8.1 kg CO_2e/m²NFA*a. The appendix contains a further chart showing the distribution of GHG emission values for different construction methods.

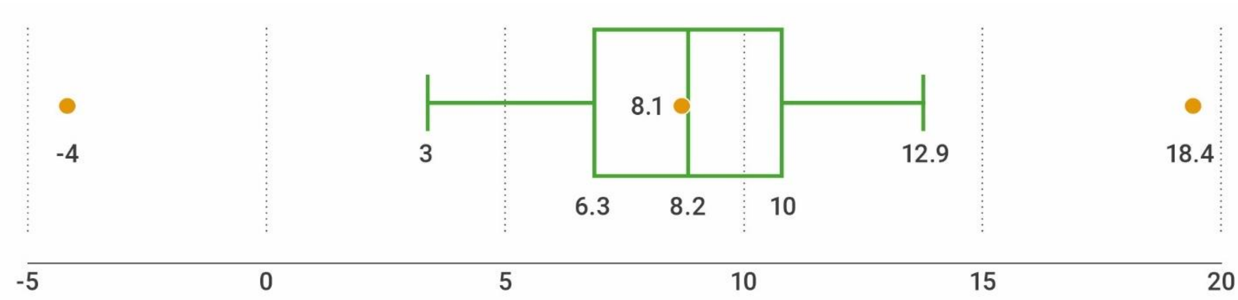

*Figure 11: Distribution of total GWP values for buildings (modules A1-A3, B4, C3, C4, D) in [kg CO_2e/m²NFA*a]*

Correlation between construction costs and sustainability results according to the DGNB

No direct correlation was found between other sustainability dimensions and construction costs.

The DGNB evaluates the degree of implementation of different sustainability factors in buildings based on a quantitative method called the ‘DGNB total performance index’. This is made up of weighted criteria covering six topics: environment, economy, socio-cultural quality, process quality, technical quality and site quality. The index makes it possible to assess sustainability holistically. The type of award given for projects depends on the score of the total performance index: platinum is achieved for a score of at least 80%, gold is awarded for 65% and above, and a silver certificate is awarded for 50% and above.

Figure 12 compares the total performance index of DGNB certification with construction costs. The circle sizes reflect the size of a building (GFA). The chart shows no correlation between construction costs and the DGNB total performance index. Projects with construction costs above €2,500/m²GFA fall under all three award levels. One observation that stands out is that among the projects with the highest (platinum) total performance index, the costs of three projects are actually lower than those awarded silver.

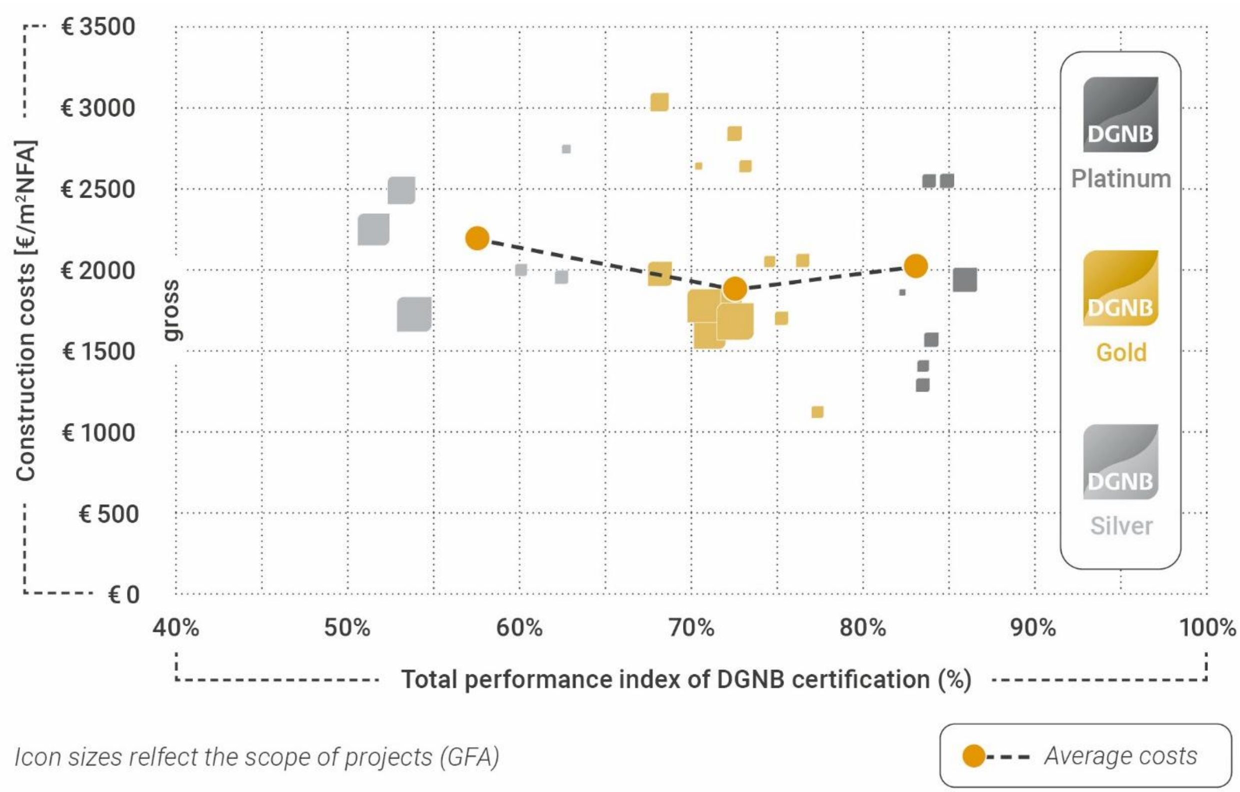

Figure 12: Correlation between construction costs and the total performance index of DGNB certification

Summary of findings and recommendations for Germany

The results of this short study can be summarised as follows:

- An evaluation of 28 DGNB-certified residential buildings shows that life cycle-optimised construction methods are not necessarily more expensive, but that compliance with life cycle GHG reference and limit values can already be achieved today with significantly lower construction costs.
- The analysis also shows that there is no obvious fundamental correlation between low CO_2 emissions from using or operating residential buildings and higher construction costs. There is a slight tendency for buildings with lower CO_2 emissions in use to also have lower construction costs. However, low CO_2 emissions in use correlate with higher levels of costs for technical systems (KG 400) as a percentage of total construction costs.
- An assessment of life cycle costs shows that in future, more focus will be needed on operation costs. Major unknowns regarding price trends, energy availability and maintenance should be key considerations when planning new buildings.
- The more energy-efficient a building is, the higher the average proportion of GHG emissions caused by the building. With older projects (certified according to DGNB Version 2015), roughly one third of emissions are accounted for by construction and around two thirds result from 50 years of use; with newer projects (certified according to DGNB Version 2018) well over 50% of emissions are accounted for by building.
- The greatest leverage for planners or architects to reduce building-related GHG emissions lies in the choice of construction methods and the materials used for the building's structural framework. Buildings with a timber structure have the lowest building-related emission values.
- Among the projects analysed for this study, no correlation was found between other sustainability factors (DGNB total performance index) and construction costs.

The analysis showed that introducing requirements for life cycle-optimised, climate-friendly construction is feasible and should not present industry stakeholders with insurmountable challenges. The task now is to prepare for their introduction and facilitate implementation. Building on earlier work, recommendations for market stakeholders and policymakers are set out below.[34]

[34] Recommendations build on the recommendations of previous publications, including DGNB 2022: Guide to Climate Positive Building Stock, BPIE 2023: Lebenszyklus-Fahrplan für Gebäude in Deutschland (Life cycle roadmap for buildings in Germany (German)), associations' requirements paper Nachhaltiges Bauen und Lebenszyklusperspektive stärken (Strengthening sustainable building and the life cycle perspective (German)), (2024).

Recommendations to German market stakeholders

1. **Further expand building LCA expertise:** In order to ensure capacity, it is important to establish life cycle assessment as a standard element of training in the existing programmes offered by training providers such as chambers of engineers and other established training institutes. Content is already available – for example the courses offered by the DGNB – so that existing programmes can be drawn upon.
2. **Establish structures for sharing knowledge on cost-effective and, at the same time, life cycle-optimised construction methods:** Learning from each other is also crucial for market stakeholders in order to share know-how on different ways to reconcile economic and environmental goals. The offer of cost planning services could be expanded to include building LCA information, alongside practice-based cost estimates and cost calculations. There are also other ways for specialist planners and architects, as well as trade journals, to share knowledge.
3. **Consider use and operation costs and environmental impacts in the early planning phases in order to reduce costs over the life cycle:** Decisions during the early stages of planning should be optimised with regard not only to building-related emissions, but also looking ahead to building use and operation, e.g. the availability of materials subject to regular maintenance. This should become a mandatory aspect of planning processes and be included as a basic service in the HOAI Fee Scale for Architects and Engineers.
4. **Support further evaluations of building LCAs and promote the harmonisation of methods:** Standard data structures should be developed in order to facilitate the analysis of building LCAs in the future, thereby making it easier to gain insights. This is less about data derived from building LCAs itself and more about obtaining more information on buildings, such as capturing good descriptions of building characteristics. Both types of information should be submitted together. In addition, all stakeholders should work together to harmonise underlying methods as well as the data used and generated, including on a European level.
5. **Stakeholders at all stages of the value chain must play their part[35]:** Although compliance with limit values can already be achieved today at low cost, efforts must continue at all life cycle stages in order to achieve the goal of making the building stock climate-neutral and turning construction into a climate-neutral industry. To this end, the manufacturers of building materials must expand the ranges of low-CO_2 products on the market, and planners and architects must consider it their mission to seek suitable offers, to request low-CO_2 products and to use those products in construction. Private financial market stakeholders are also urged to offer financing that supports more climate-friendly construction under improved terms and conditions – which is also in their own interests – so as to avoid depreciation and loan defaults due to climate risks.

[35] For more detailed recommendations per stakeholder group see e.g. DGNB 2022: Guide to Climate Positive Building Stock, or BPIE 2023: Lebenszyklus-Fahrplan für Gebäude in Deutschland (Life cycle roadmap for buildings in Germany (German))

Recommendations to German policymakers

1. **Introduce a life cycle regulation for buildings at an early stage, involve market stakeholders via participation initiatives, and bolster and consolidate the sharing of experience with other EU member states:** Given the forthcoming implementation of the EPBD, which requires member states to introduce building LCAs and develop national roadmaps for implementing life cycle limit values, Germany should move early and define mandatory life cycle limit values, i.e. before the deadlines for implementing the EPBD[36]. After all, experience gained in frontrunner countries that do have a whole life carbon regulation already in place shows that early, step-by-step approaches encourage the development of building LCA expertise and improve the availability of sustainable products.[37] During the introductory phase, it is crucial to involve market stakeholders and launch participation initiatives such as round tables for implementation as quickly as possible. In-depth and ongoing dialogue with EU countries is also recommended in order to institutionalise the process of mutual learning.
2. **Expand the role of public sector building owners/clients in setting an example:** To improve knowledge and practice around cost-optimised climate-neutral buildings, the public sector must take a much stronger lead and set itself the goal – as quickly as possible – of creating life cycle-optimised zero-emission buildings, both new and existing. To this end, the expected life cycle GHG limit values must be demanded at federal, city and local authority level in pitches, tenders and when awarding planning and construction contracts.
3. **Inform market stakeholders early and prepare them for upcoming changes, also pointing to opportunities and risks:** The introduction in Germany of the new zero-emission building standard for all new buildings from 2030 onwards (for public buildings from 2028), which is rooted in the EU's Energy Performance of Buildings Directive (EPBD), should be defined in concrete terms as early as possible through active involvement and open dialogue with market stakeholders. This should also be established in funding and legal requirements. In particular, the opportunities offered by changes and the risks of standing still should be presented objectively and made public to market stakeholders. This will secure and expand employment opportunities and actively support efforts to enable transformation in the energy industry.
4. **Address the building of climate-friendly social housing through targeted funding programmes and strengthen expertise in life cycle-optimised construction:** Economical, socially-oriented construction that saves money, materials and energy should become an element of future funding alongside all necessary subsidies for the transformation of existing buildings. Subsidies – such as those under the German Federal Funding for Efficient Buildings scheme (BEG) – should be targeted at the renovation of residential buildings so as to ensure that investments in climate action measures focus particularly strongly on such properties. Funding opportunities should also be created for planners and contractors to develop the necessary expertise for life cycle-optimised construction.

[36] EPBD: from 2028 for large buildings, 2030 for all new construction
[37] BPIE 2023: Regulierung der Lebenszyklus-THG-Emissionen von Gebäuden. Wie gehen andere EU Mitgliedsstaaten vor? Wo steht Deutschland? (Regulation of life cycle GHG emissions from buildings. What are other EU member states doing about it? Where does Germany stand? (German))

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About the German Sustainable Building Council (DGNB)

Founded in 2007, the DGNB is now Europe's largest network for sustainable building with around 2,500 member organisations. The aim of the association is to promote sustainability in the construction and property industry and to anchor it in the consciousness of the general public. With the DGNB certification system, the independent non-profit organisation has developed a planning and optimisation tool for evaluating sustainable buildings and districts in order to promote genuine sustainability in construction projects. The DGNB System is based on a holistic understanding of sustainability that takes equal account of the environment, people and economic efficiency. In addition, more than 10,000 people in around 60 countries have already qualified as experts in sustainable building via the DGNB Academy education and training platform.

Further information can be found at https://www.dgnb.de/en

About BPIE – Buildings Performance Institute Europe

BPIE (Buildings Performance Institute Europe) is a European non-profit think tank that uses independent analyses and data collection to make research contributions to a carbon-neutral building stock and feeds these into the political debate at EU level and in the European member states. BPIE's work focuses on the evaluation of policy instruments and programmes and the identification of technological solutions and social innovations to reduce energy consumption and promote renewable energy in the European building sector. BPIE also emphasises the importance of healthy homes and the need for a life cycle approach in order to embed sustainability along the entire value chain. In addition to its headquarters in Brussels, since 2014 the Institute has maintained a further office in Berlin, resulting in a particular focus on building-related policy development in Germany.

Further information can be found at: www.bpie.eu

Suggested citation: DGNB/BPIE 2025: Life cycle-based assessment of buildings: An analysis of 28 residential buildings with regard to climate impact and costs in Germany.

Appendix

Further to Figure 3, Figure 13 shows the GHG emissions of buildings for all projects and the total value of all modules (A1-A3, B4, C3, C4 and D).

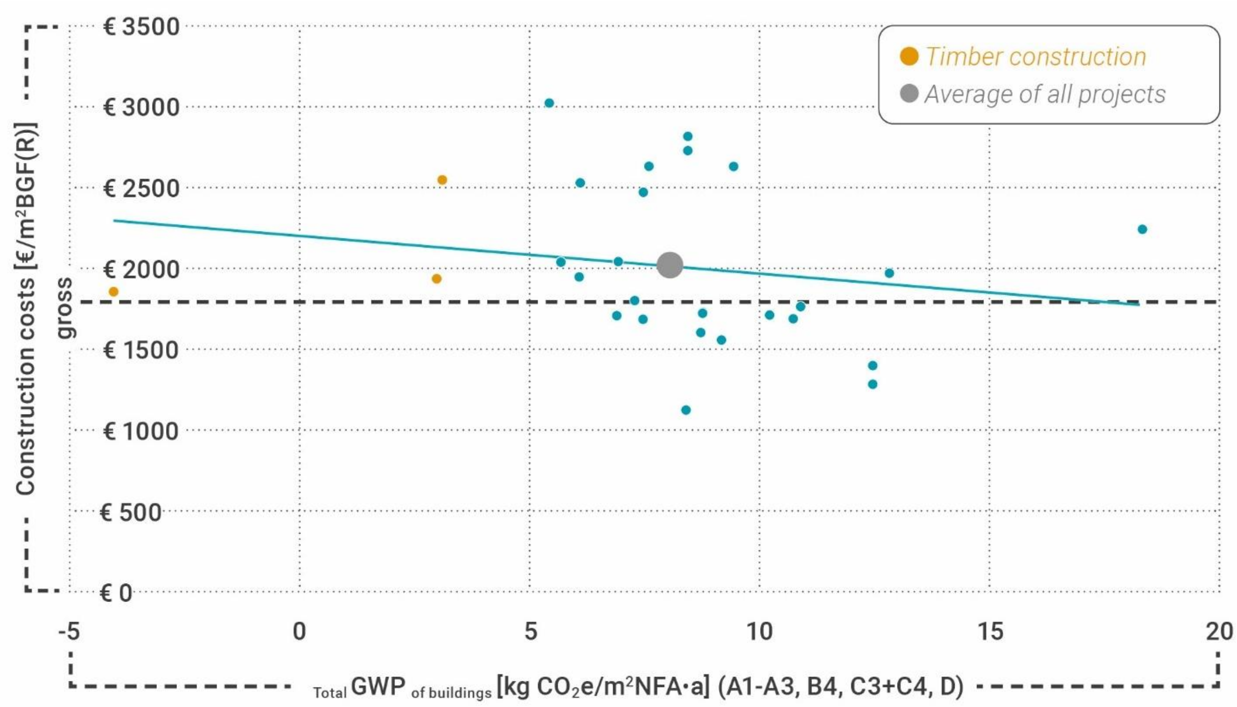

Figure 13: Correlation between CO_2 emissions over the life cycle of the building and construction costs

Further to Figure 10, Figure 14 shows the GHG emissions of buildings (modules A1-A3, B4, C3, C4, D), ascending according to the structural system.

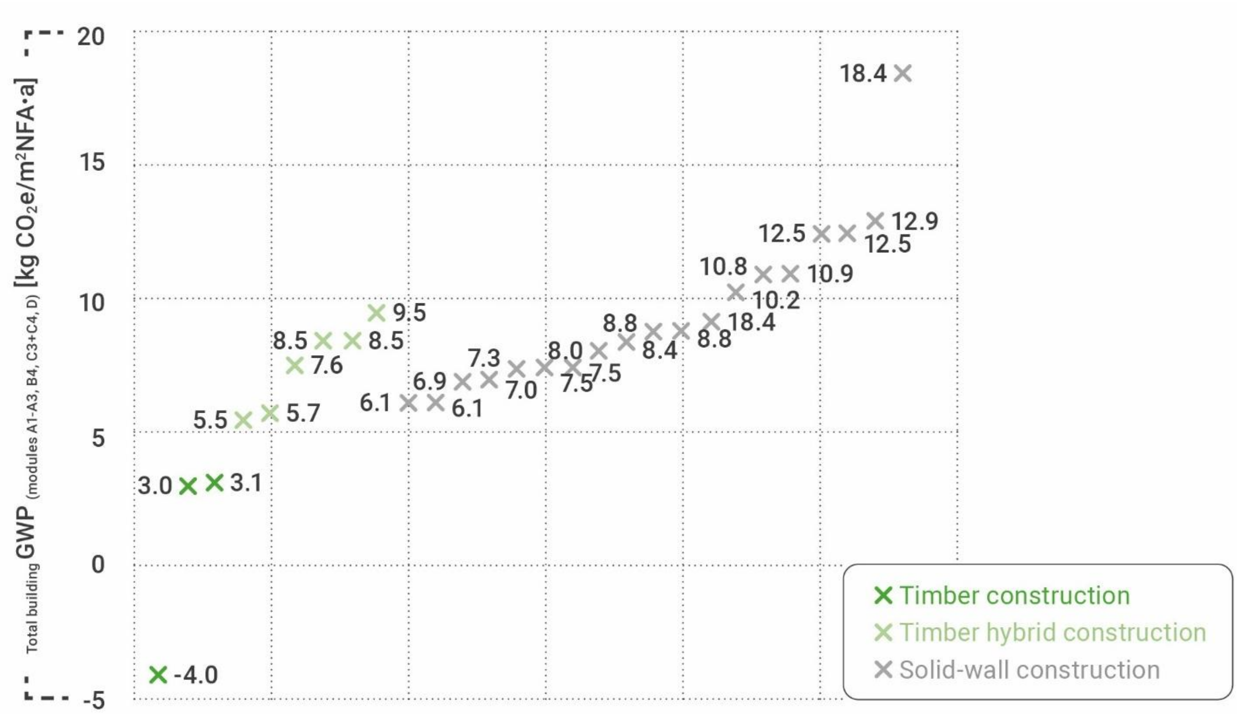

Figure 14: CO_2 emissions over the life cycle of buildings depending on the construction method of the structural framework (shown in ascending order)