# Beyond operational Efficiency

**Evaluating Building Energy Standards and Design Choices for both operational and embodied emissions**

Wissenschaftliche Arbeit zur Erlangung des Grades
M. Sc. Civil Engineering
an der TUM School of Engineering and Design der Technischen Universität München.


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# Abstract

**Purpose**

This study evaluates and compares various building design standards to determine which leads to the lowest life cycle emissions. By examining different energy standards and design choices, this research provides insights into sustainable building practices that minimise environmental impact throughout a building's life cycle.

**Methodology**

The research methodology involves a comprehensive Life Cycle Assessment for a case study building and different variants. The LCA was conducted by using the software eLCA. Building energy simulations were conducted to assess the impact of the design decisions on the operational emissions. The simulation software Rhino and Honeybee were used. Furthermore, the variants were analysed under various scenarios to compare their life cycle emissions if the system boundaries of the LCA are expanded.

**Findings**

No clear energy standard can be singled out as the best-performing energy standard as it highly depends on the system boundaries chosen and the actual energy demand that has to be covered by the on-site energy production. However, the results highly depend on the chosen system boundaries. Furthermore, changing to sustainable building materials results in higher energy demand but does not automatically lower the LCE of a building. Nonetheless, two key findings concerning design decisions could be identified:

1) All scenarios showed that the amount of insulation materials used in the base case to reduce the energy losses of the building was too much as a lower energy performance can potentially produce less LCE. Highlighting that when evaluating the performance of a building, embodied emissions should also be considered.

2) The analysis showed that the full potential of onsite energy production should be harnessed as all variants with the same energy demand performed better the more PV modules were installed.



**Keywords:**

Embodied emissions, life cycle emissions, design standards, life cycle assessment, energy simulation, operational emissions, sustainable building, and energy-efficient design.

# List of Abbreviations

| | |
|---|---|
| BNB | Bewehrtungssystem nachhaltiges Bauen (Assessment system for sustainable construction) |
| BEM | Building energy model |
| BES | Building energy simulation |
| BREEAM | Building Research Establishment Environmental Assessment Methodology |
| CG | Cost group |
| DGNB | Deutsche Gesellschaft für Nachhaltiges Bauen (German Association for Sustainable Building) |
| EC | Embodied carbon |
| EnEV | Energieeinsparverordnung (Energy Saving Ordinance) |
| EPBD | Energy Performance of Building Directive |
| EPD | Environmental Product Declaration |
| EPG | Energy performance gap |
| EPS | Expanded polystyrene foam |
| GEG | Gebäude Energie Gesetz (German Building Energy Act) |
| GHG | Greenhouse gas emissions |
| GWP | Global warming potential |
| HB | Honeybee |
| HVAC | Heating, ventilation, and air conditioning systems |
| ISO | International Organization for Standardization |
| KfW | Kreditanstalt für Wiederaufbau (German Credit Institute for Reconstruction) |
| LCA | Life cycle assessment |
| LCE | Life cycle emissions |
| LCI | Life cycle inventory |
| LCIA | Life cycle impact assessment |
| LEED | Leadership in Energy and Environmental Design |
| NZEB | Nearly zero energy building |
| OC | Operational carbon |
| PV | Photo -Voltaic |
| PCR | Product category rules |

| | |
|---|---|
| QNG | Qualitätssiegel Nachhaltiges Gebäude (Quality seal for sustainable buildings) |
| QSS | Quasi-steady-state building energy simulations |
| SCC | Social cost of carbon |

# Glossary

**Embodied emissions**
Total greenhouse gas emissions produced during the manufacturing, transportation, installation, maintenance, and disposal of building materials.

**Energy performance gap**
The difference between the expected energy performance of a building (based on design specifications) and the actual energy performance observed during operation.

**Energy standard**
Regulations or guidelines that specify the minimum energy performance requirements for buildings or appliances to ensure energy efficiency and reduce consumption.

**Final energy demand**
The amount of energy consumed directly by a building for its operation, including heating, cooling, lighting, and powering appliances. This measure reflects the energy that is actually delivered to and used within the building, excluding any energy lost during generation, conversion, or distribution.

**Functional Unit**
A quantified description of the performance of a product system for use as a reference unit in a life cycle assessment (LCA).

**Greenhouse gas emissions**
Emissions of gases that trap heat in the atmosphere, contributing to global warming and climate change. Examples include carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$).

**HVAC**
Heating, ventilation and air conditioning building equipments used to regulate the indoor climate of buldings.

**LCA**
A systematic analysis of the environmental impacts of a product, process, or service throughout its entire life cycle, from raw material extraction to disposal.

**Life cycle emissions**
Total greenhouse gas emissions associated with a product or process over its entire life cycle, including production, use, and disposal stages.

**LCI**
A phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product system throughout its life cycle.

**Operational emissions**
Greenhouse gas emissions resulting from the use phase of a building or product, primarily from energy consumption for heating, cooling, lighting, and equipment operation.

**Primary energy demand**
The total amount of energy required to meet the energy needs of a building, including heating, cooling, lighting, and other operational energy uses. It encompasses all upstream energy inputs needed to generate and supply this energy, considering extraction, conversion, and distribution losses.

**PV-module**
Photovoltaic module, a component of solar panels that converts sunlight into electricity.

**Thermal Transmittance**
The rate at which heat passes through a material or building component, also known as U-value. Lower values indicate better insulation properties.

**Time value of carbon**
Concept that emphasizes the importance of the timing of carbon emissions reductions, recognizing that earlier reductions have a greater impact on mitigating climate change than later reductions.

# 1 Introduction

## 1.1 Background and Motivation

In their building sector report, the UN once again highlights the enormous impact of the industry on the environment. At least 37% of global greenhouse gas emissions (GHG) can be allocated to processes in the building industry for construction, operation, and demolition (UNEP, 2023). Similar shares in emissions can be observed in the EU (36%) and Germany (40%) (BBSR, 2020; European Commission, 2020). Therefore, the building sector must play a key role in reducing these environmental impacts on our way to a more sustainable future. The European Commission issued the Energy Performance of Building Directive (EPBD) as a step toward a sustainable building sector. The updated directive requires that all new buildings in EU countries be designated as nearly zero energy buildings (NZEB). NZEBs require almost no energy during the operational stage of a building, and most of this energy is covered by renewable sources. From 2027 onwards, the directive will become even stricter as new buildings must reach a zero-energy building standard. These buildings will then require even less energy, with the remaining deficient energy needed to be fully covered by renewable sources. (European Commission, n.d [2021] This operational energy-efficient first principle may currently be the right approach as a majority of the energy emitted stems from the operational stage (Marzouk & Elshaboury, 2022). The UN estimates that of the sector's emissions, 75% are solely for operating the building. However, in the scientific literature, considering both embodied and operational emissions and weighing off between them receives growing attention as the focus on reducing the operational efficiency of a building entails larger quantities of building material and technical equipment. This sole focus on reducing operational emissions (OE) might increase the life cycle emissions (LCE) if the holistic view is lost (Marzouk & Elshaboury, 2022), which in turn would lead to the loss of the initial purpose of the EPBD, reducing the emissions of the building sector.

## 1.2 Purpose and Goals

Therefore, this master’s thesis will answer the following research question: Which building energy standard and design decisions, accounting for embodied and operational emissions, offer the most effective pathway toward sustainable construction in non-residential buildings? The following hypotheses will be examined on the example of a school building in Germany:

1) An overall lower energy standard, e.g., passive house, could reach better energy and carbon emissions performance over a 50-year life cycle.
2) A focus on sustainable building materials for the hull, like wood fibres or straw, can reduce the overall LCE while the share of operational emissions increases

3) The results vary depending on the following system boundaries:
    a. inclusion of Module D - benefits and loads beyond the system boundary in the life cycle assessment (LCA)
    b. inclusion of a decarbonising energy mix
    c. weighing of future carbon emissions

To answer these questions and to validate the hypothesis, the thesis focuses on the major renovation of a school building in Stuttgart, Germany. The main renovation goal was to reduce the operational energy demand of the building to a minimum and produce enough energy on-site using solar panels on the roof and the façade so that the school would produce more energy over a year than it needs. The designers employed many energy-intensive renovation techniques for the heating, ventilation, air conditioning systems (HVAC), and hull to reach low energy demand during operation. (Wenger, 2018) However, based on the research, whether this refurbishment method is truly the most sustainable option is questionable. Therefore, energy simulations of the case study and the variants, in combination with quantifying the embodied emissions during the construction, will evaluate whether better design options could have yielded lower life cycle emissions.

To provide an overview, the following is a breakdown of the thesis structure: In Chapter 2, the theoretical background to asses LCE is explained by first defining LCE, highlighting the impact energy standards and design decisions can have on the LCE and introducing the methodology to asses potential environmental emissions: Life-Cycle- Assessment (LCA). Chapter 3 introduces the design decisions of the case study and how these are varied. Furthermore, the system boundaries of the LCA and the energy simulation are defined. Chapter 4 describes how the introduced methodology is applied to the case study and the variants. In Chapter 5, the results of the variant study are shown and discussed. Several limitations and future fields of research are shown in Chapter 6. Lastly, the research questions are answered, and the hypotheses are proven or unproven.

# 2 Theoretical Background of Life Cycle Emissions and how design standards influence them

This chapter outlines the theoretical background of assessing a building's LCE. Different design standards and the corresponding design decisions that influence the operational performance of a building are examined. Furthermore, the current standards for Life cycle assessment and energy simulation in the building industry are presented. Lastly, two concepts regarding the dynamic development emissions in the future and how these can be accounted for are introduced.

## 2.1 Desing decisions and energy standards influencing the life cycle emissions

### 2.1.1 Life cycle emissions

From a cradle-to-grave perspective, the life cycle of a building consists of four different phases: A – Building construction, B – Operation, C – Demolition, and D - Recycling (cf. Figure 2-5). The sum of greenhouse gas emissions (GHG) emitted during the life cycle of a building is called life cycle emissions (LCE). These can be divided into operational emissions (OE) and embodied emissions (EE). OE are emitted in phase B during the building's operation through electricity, heating and cooling energy, and the burning of fossil fuels. (Liang et al., 2022)

In the literature, EE refers to all GHG associated with producing and using a material or product. It includes two main parts. First, the fuel-related emissions. These GHGs are released when fuel is burned to make or transport the material to the fabrication plant and the construction site. It does not count the energy already in the material itself. Secondly, the process-related carbon emissions. These emissions occur during manufacturing but do not stem from burning fuel. For example, during the calcination of limestone in the cement industry, The EE of a product can, therefore, occur during the entire life cycle of a building (phases A-D). (Cabeza et al., 2021; Hammond et al., 2011)

In recent years, the literature has highlighted the importance of accounting for EE and looking beyond the operational efficiency of a building (John Orr et al., 2018; Mahler et al., 2019). Marzouk and Elshaboury (2022) investigated the increased research activity in EE. Figure 2-1 shows the increasing number of publications in recent years.

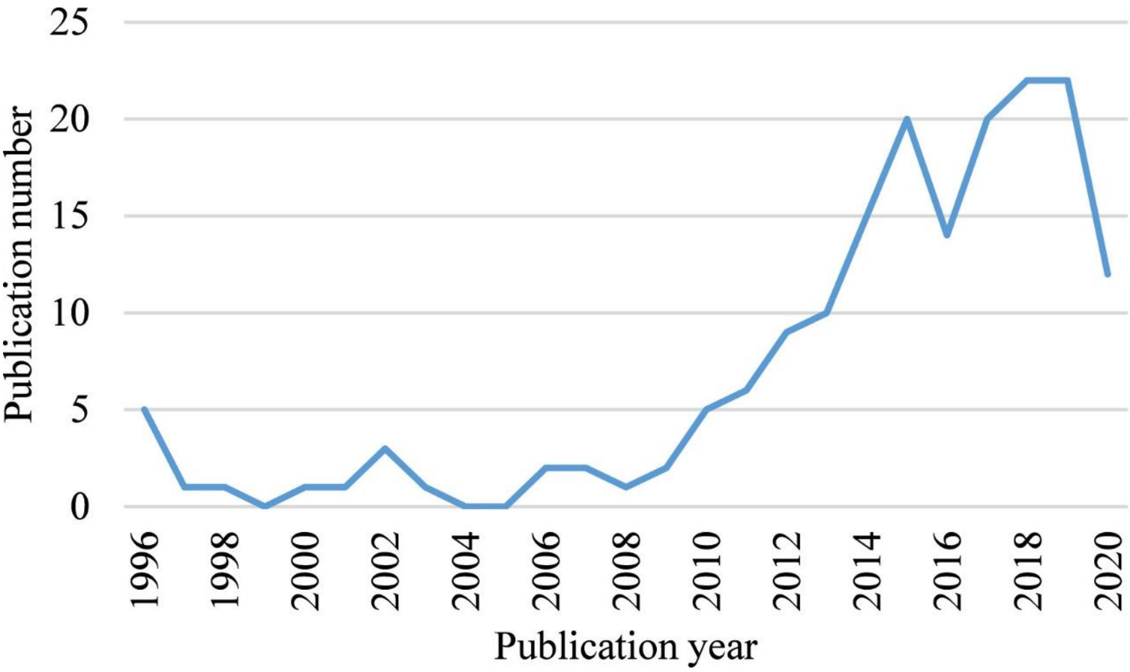



**Figure 2-1: Increases in the research activity of EE in the construction sector. (Marzouk & Elshaboury, 2022)**

Furthermore, it is well established that with regulations like the Energie-einsparverordnung (Energy Saving Ordinance, EnEV) and Gebäude Energie Gesetz (German Building Energy Act, GEG) in Germany or the goal of achieving Net Zero Emission Building in the EU, the dominance of OE in the life cycle emissions of the building shifts towards the EE (Azari & Abbasabadi, 2018; John Orr et al., 2018; Koezjakov et al., 2018; NBBW, 2022). The development of the share of OE and EE of the LCE of a building is shown in Figure 2-2. Note that the circle's size indicates a building's LCE.

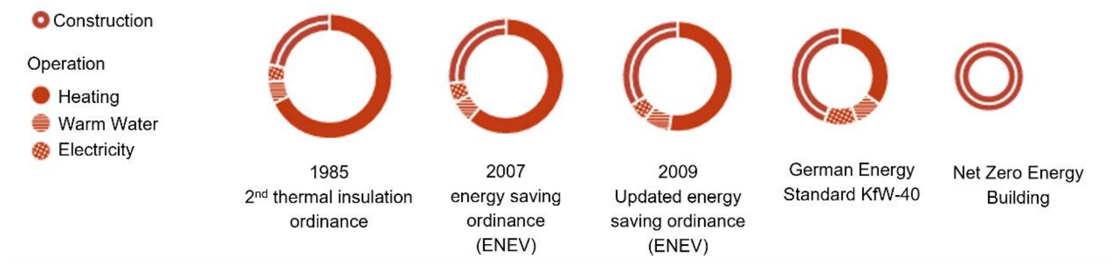



**Figure 2-2: Share of operational and embodied emissions for different energy standards in Germany (translated from NBBW, 2022)**

The reasons for this shift are that the energy efficiency of the building hull and technical equipment has to increase to reduce the OE. In most cases, this goes hand in hand with increased material and more complex technical equipment, which results in higher EE. (Koezjakov et al., 2018) So far, this focus on reducing OE has resulted in an overall decrease in LCE. However, recent studies showed that certain measures to achieve these high energy-efficient building standards require massive investments into building materials for the hull and technical building equipment, resulting in high carbon emissions during construction and higher life cycle emissions. A case study in Norway showed that finding an equilibrium between EE and OE in residential NZEBs is impossible in a scenario with a low-carbon electricity grid, and EE becomes more significant the cleaner the electricity grid is. (Georges et al., 2015) Similar results were shown in a study on a four kWp photovoltaic system from China that was theoretically installed across 76 European locations. It revealed that in countries with low annual solar yield and an already high share of green electricity in the grid, the overall environmental impact of PV systems might be negative, as seen in Sweden, Iceland, and Norway. (Martinopoulos, 2020a) Furthermore, a case study of three houses with different energy standards in Australia showed that if the environmental emissions of future energy mixes are considered, the share of the environmental emissions stemming from the building materials increases drastically (Norouzi et al., 2022). Another study showed that upfront emissions of advanced energy-saving buildings dominate the timeframe for climate change mitigation and, in a dynamic case with adjusted emissions, outperform the operational emissions for a timeline of 50 years. Subsequently, the EE must be reduced if we want to reach the climate goals. In addition, it highlighted the importance of the temporal distribution of emissions. (Röck et al., 2020) Lastly, Mahler et al. (2019) showed that heat recovery systems are only minimally effective in reducing the total LCE of a building if it is heated with fossil fuels. Furthermore, they showed that a whole-year self-sufficient building releases more emissions in its entire life cycle than a building that still relies on energy from the grid.

Reducing emissions during the operational stage makes the EE in the building life cycle more critical. In addition, measures to reduce OE can lead to higher LCE if a decarbonised energy grid and too many resources are used to achieve these better energy standards.

### 2.1.2 Energy Standards in Germany

Building energy standards represent a legal requirement from legislation, codes, or artificial definitions to claim a certain title, like a passive house, from the literature. Both, however, set benchmarks for the energy demand and onsite energy production of a building and, therefore, influence the design decisions of a building. (Badr et al., 2018) In Germany, the “Gebäude Energy Gesetz” (Building Energy Directive, GEG) defines the base energy standard for a new building. In this case, the primary energy demand for a new building is 55% less than that of a reference building. The reference building has the same geometry, orientation, usage, and surface areas as the original building. However, design decisions, like the make-up of the building envelope, follow the minimum benchmarks defined in the GEG and the DIN V 18599: 2018-09. Besides the minimum energy performance, the GEG defines a minimum amount of thermal insulation. (GEG, 2020/10/16/2023) Building on the base energy standard defined by the GEG, the “Kreditanstalt für Wiederaufbau” (German Credit Institute for Reconstruction, KfW) defines benchmark energy standards regarding the primary energy demand and transmission heat loss in exchange for granting funding for a sustainable building.

Besides these standards defined by the GEG & KfW, the literature describes the following energy Standards: passive houses (heating energy demand max. 15 kWh(m$^2$ a), zero-energy buildings (annual end-use energy demand = 0), and plus-energy buildings (annual final and primary energy demand < 0) (Mahler et al., 2019). Table 1 gives an overview of the different energy standards. Theoretically, a zero-energy building or an energy-plus building could be reached with all energy standards as long as the onsite energy production produces enough energy to cover the yearly demand.

**Table 1: Established Energy Standards for new buildings in Germany. (GEG, 2020/10/16/2023; Mahler et al., 2019)**

| Energy Standard | System Boundaries | Requirements |
|---|---|---|
| GEG – Base Case | Building energy demand according to GEG, without user electricity demand | 55% less energy demand than the reference building and minimum thermal transmittance |
| KfW - 40 | Building energy demand according to GEG, without user electricity demand | 40% less energy demand and transmission heat loss of 55% than the reference building |
| Passive House | Building energy demand according to GEG, with user electricity demand | Heating requirement < 15 kWh/(m$^2$ *a), Non-renewable primary energy PE < 95 kWh/(m$^2$ *a) |
| Zero Energy Building | Building energy demand according to GEG, with user electricity demand | Annual end-user energy demand = 0 |
| Plus Energy Building | Building energy demand according to GEG, with user electricity demand | Primary energy demand < 0 |

### 2.1.3 Design Decisions Influencing Operational Emissions

As energy standards limit the energy demand in a building, optimised design strategies are used to reduce operational emissions. Different parameters influence the energy demand of a building. The literature defines four groups of parameters that influence the energy demand: the building (form, material and construction), the system (electrical appliances, HVAC), the occupant (household statistics and energy-related behaviour) and the context (geometry, urban and local climate). These four areas govern the gains and losses of a building's external and internal energy sources. (ALI-TAGBA et al., 2024; Steemers & Yun, 2009) From a design perspective of a single building, only two areas can be influenced: the building and the system. Table 2 lists an overview of the different parameters of these groups and links them to how they can influence the energy demand of a building.

**Table 2: Different building design parameters that influence the energy demand.**

| Parameter | Description | Source |
|---|---|---|
| Envelope Materials | The materials used for walls, roofs, and floors significantly affect thermal insulation and energy demand. | (Granadeiro et al., 2013; M. Najjar et al., 2019) |
| Window-to-Wall Ratio (WWR) | The WWR affects natural lighting, heating, and cooling loads. | (M. K. Najjar et al., 2019; Xu et al., 2018) |
| Insulation Thickness | The insulation thickness in walls, roofs, and floors impacts the building's thermal resistance and energy efficiency. | (Xu et al., 2018) |
| Thermal Performance of Windows | The windows' U-value and solar heat gain coefficient (SHGC) influence heat loss and solar gains. | (Jezierski & Sadowska, 2022) |
| Building Shape | The shape and compactness of the building affect its surface area to volume ratio, influencing heat loss and gain. | (Granadeiro et al., 2013) |
| Orientation | The orientation of the building determines the exposure to sunlight and wind, affecting heating and cooling loads. | (M. Najjar et al., 2019; Rouleau et al., 2018) |
| Natural Ventilation | The design of ventilation systems, including the size and placement of openings, affects indoor air quality and energy demand. | (Heeren et al., 2015) |
| Shading Devices | External and internal shading devices can reduce cooling loads by minimising solar heat gain. | (Heidari et al., 2021; Koç & Maçka Kalfa, 2021) |
| Building Mass | The thermal mass of the building materials can moderate indoor temperature fluctuations and reduce energy demand. | (Heeren et al., 2015) |
| HVAC Systems | The efficiency and design of heating, ventilation, and air conditioning (HVAC) systems directly impact the energy demand for climate control. | (Gravia Pimenta et al., 2022) |
| Building Automation and Control Systems | Effectively designed and accurately implemented Building Automation and Control Systems can potentially decrease energy consumption in buildings. | (van Thillo et al., 2022; Vandenbogaerde et al., 2023) |
| On-Site Energy Production | Integrating renewable energy systems, such as photovoltaic panels, can reduce the reliance on external energy sources and lower overall energy demand. | (Bot et al., 2019; Cody et al., 2018) |

Although these measures reduce buildings' energy demand, most entail increased embodied energy (cf. Chapter 2.1.1). Therefore, the overall LCE have to be assessed to be able to make the right design decisions.

# 2.2 Life Cycle Assessment

Life cycle assessment is a method to quantify the potential environmental impacts, such as GHGs, of products, processes, and services over their entire life cycle. It is, therefore, a method to assess the LCE of a building (Hauschild et al., 2018). In this chapter, the general methodology of LCA is explained, as well as how the methodology is applied in the building sector.

## 2.2.1 Life Cycle Assessment Methodology

The International Organisation for Standardisation (ISO) defined a basic framework and fundamental principles for an LCA in the series ISO 14040 and ISO 14044 (Cabeza et al., 2014; Hauschild et al., 2018). Part of this framework is the defined iterative process consisting of the goal and scope definition, inventory analysis (LCI), impact assessments (LCIA), and an ongoing interpretation (cf. Figure 2-3) (ISO, 2006).

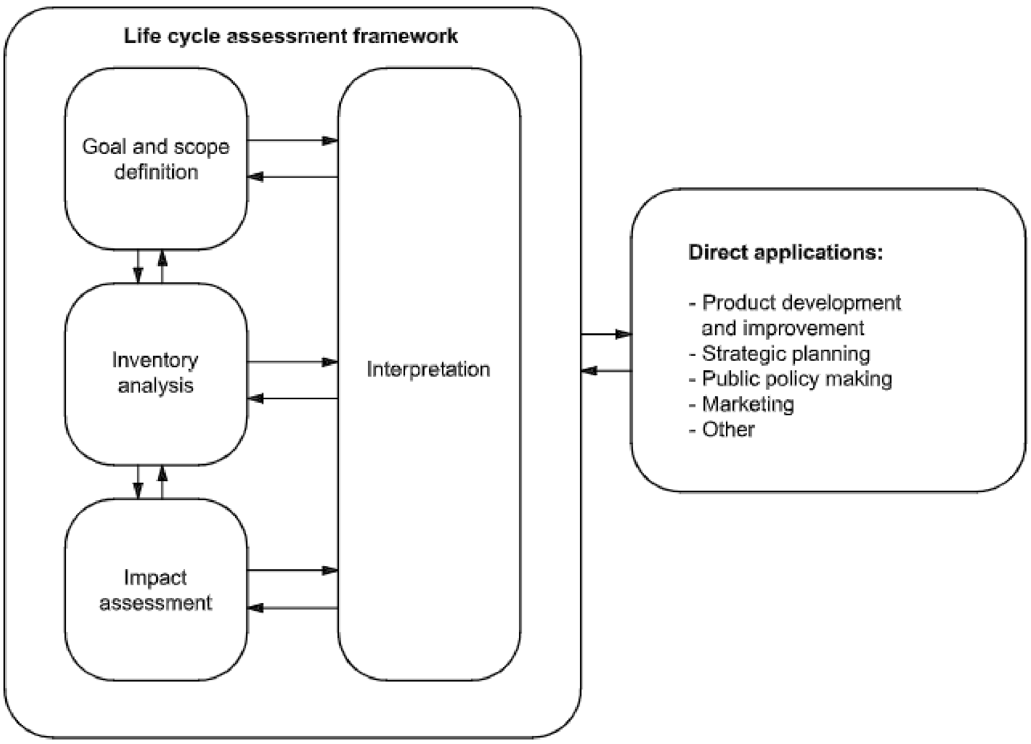



**Figure 2-3: Stages of an LCA according to the ISO 14040 (ISO, 2006)**

#### 2.2.1.1 Goal and Scope Definition

The goal definition defines and describes the study's purpose and includes the following six aspects. Hauschild et al. (2018) define these as the following. Firstly, the intended application of the results of the study. This means, for example, comparing the environmental impacts of a specific good like regular concrete and recycling concrete.

Secondly, the limitations due to methodological choices are mentioned. LCA results are limited by the specific scope and choices made during the study; for instance, results from a global warming potential (GWP) footprint study cannot claim the overall environmental superiority of a product. Additionally, these limitations should be clearly outlined in the goal and scope phases of an LCA. In contrast, unforeseen constraints and assumptions made during later phases need separate documentation within the LCA report.

Thirdly, the study's reason and the decision's context should be given. Fourth, the target audience should be mentioned as it shapes the level of detail, technicality of reporting, and interpretation of study findings. Furthermore, the goal statement should clarify if the study is comparative and whether it is meant for public disclosure, which, if applicable, entails following specific rules from the ISO standards to ensure transparency and quality.

At last, the commissioner of the study and other influential actors should be mentioned to showcase if there are potential conflicts of interest in the study.

The scope definition is the second part of the analysis, which has multiple parts. On the one hand, it defines the reporting and communication of the LCA and sets the boundary conditions for conducting the LCA. The main goal of defining the scope is to guarantee and record that the methods, assumptions, and data used are consistent, thus enhancing the study's reproducibility. Essential parts are the definition of a functional unit, system boundaries, the representativeness of the LCI, and preparing the basis for the LCIA. (Hauschild et al., 2018)

A functional unit is a measure in LCA to quantify the performance or function of a product or system. It answers the following questions: “What?”, “How much?”, “For how long?”, “Where?” and “How well?”. Furthermore, the system boundaries are defined in it. These define the boundaries between the assessment, the surrounding economy, and the environment. For example, in the construction industry in Germany, certain “Kostengruppen” (cost groups, CG) defined in DIN 276 can be excluded in an LCA of a building. CG 400 includes all technical building systems. Comparing the results of an LCA where cost group 400 is or is not included would not be possible. The scope definition outlines the LCI requirements to ensure data accuracy, which is crucial for the analysis and interpretation of results. This step addresses crucial constraints like geographical data representativeness, time-related representativeness, and technological representativeness. At last, the scope defines which impact categories are included in the LCIA and why specific categories are not. (Hauschild et al., 2018)

#### 2.2.1.2 Inventory Analysis

The LCI lists all inputs and outputs associated with the entire life cycle of a product or process. These outputs serve as input for the subsequent LCIA. The LCI includes information about energy consumption, material usage, emissions, waste generation, and other relevant factors. (Hauschild et al., 2018) Technical programs like Simapro, eLCA, and Athena can support practitioners in creating the LCI and linking the outputs to the LCIA (Athena Sustainable Materials Institute, 2024; Figl et al., 2017; PRé Sustainability, 2024).

#### 2.2.1.3 Impact Assessment

Though the method for the LCIA is mainly controlled by the chosen program and the underlying method, it is important to understand the basic principles. LCIA evaluates the environmental significance of elementary flows within a product system by examining their contributions to environmental impacts using impact categories and indicators. This means that during the LCIA, the outputs, such as emissions, are linked towards a specific impact category at a midpoint or endpoint, such as GWP (midpoint) or human health (endpoint). (Hauschild et al., 2018) Midpoint indicators are the preliminary stage to the endpoint indicators and are problem-oriented, meaning they describe the potential impact on an environmental category. On the other hand, endpoint indicators are damage-oriented, depicting the outcomes of adverse environmental effects on humans and ecosystems. They signify the culmination of a potential series of causes and effects. However, they come with a downside of increased uncertainty in the findings due to the involvement of more environmental mechanisms. (Blom et al., 2010) The midpoint approach is currently favoured as it allows for more reliable assessments (Weißenberger, 2016).

To evaluate the impact on these categories, the outputs are characterised to assess the degree to which they contribute to an impact. For midpoint indicators, the impact is described in a reference substance; for GWP, this would be kg $CO_2$-equivalents. (Hauschild et al., 2018) Table 3 gives an overview of the typical impact categories at the midpoint and their reference substance that are part of LCAs.

**Table 3: Description of frequently used impact categories and assessment parameters (translated from Goldstein & Rasmussen, 2018; Weißenberger, 2016)**

| Impact Category or Evaluation Parameter | Abbreviation | Unit | Brief Description | Public Awareness | Frequency in LCA studies |
|---|---|---|---|---|---|
| Primary energy content total / non-renewable/renewable | PE_total/n.e./e. | kWh (MJ) | Measure for energy efficiency and the depletion of resources | First oil crisis (Resource consumption): 1973 | often |
| Global Warming Potential (GWP) | GWP | kg $CO_2$-eq. | Influences global warming negatively | UN Climate Conference: 1992 | often |
| Ozone Depletion Potential (ODP) | ODP | kg CFC11-eq. | Degrades the stratospheric ozone layer | Ban on CFCs in sprays in the USA: ca. 1978 | less |
| Acidification Potential (AP) | AP | kg SO2-eq. | Causes acidification of soil and water | Forest dieback (Spiegel article): ca. 1980 | less |
| Eutrophication Potential (EP) | EP | kg PO4-eq. | Causes nutrient enrichment in waters and soils | Phosphate-free detergents: ca. 1990 | less |
| Photochemical Ozone Creation Potential (POCP) | POCP | kg C2H4-eq. | Promotes the formation of tropospheric ozone (summer smog) | Catalytic converter law in the USA: ca. 1975 | less |
| Abiotic Depletion Potential (Materials) | ADP | kg Sb-eq. | Measure for resource scarcity | First oil crisis (Resource consumption): 1973 | less |

Optional steps according to the ISO norms are normalisation, weighing, and grouping. (Hauschild et al., 2018) Normalisation involves comparing a measured impact to a reference value, ensuring all impacts are comparable. Weighing involves multiplying normalised results of impact categories by a factor reflecting their relative importance. The weighted results share a common unit and can be summed to yield a single score representing the overall environmental impact of a product or scenario. The results depend on the underlying program and methodology for the LCIA. (Iswara et al., 2020) An overview of the complete LCA process and LCIA method is shown in Figure 2-4.

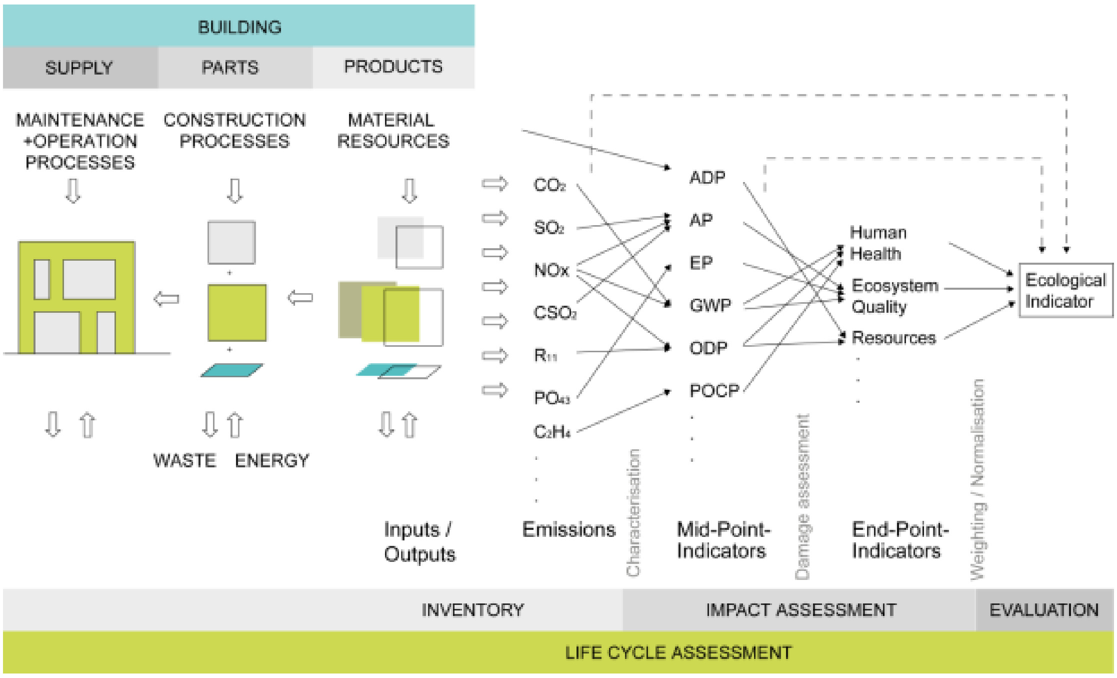



**Figure 2-4: LCA process and LCIA methods using the example of a building (E. P. Schneider-Marin, 2022)**

### 2.2.1.4 Interpretation

Interpretation in LCA consolidates and evaluates results while considering data uncertainties and study assumptions. Its goal is to derive conclusions or recommendations aligned with the study's objectives and constraints, presenting them understandably while addressing potential weaknesses. Sensitivity and uncertainty analyses are central to interpretation and are integrated iteratively throughout the LCA process. This phase involves three steps: identifying significant issues from previous phases, assessing robustness, and presenting conclusions. (Hauschild et al., 2018)

## 2.2.2 LCA in the Building Industry

Since its development, LCA has become one of the most established frameworks for analysing the environmental impact of building products and entire buildings. This is highlighted by increased research concerning LCA in the building industry. Anand and Amor (2017) showed that from 2011 – 2015, the number of buildings-related publications increased by 300%, and Yılmaz and Seyis (2021) observed a similar increase from 2015-2021. Furthermore, establishing EU Norms for LCA in the building industry confirms this trend. EN 15978 gives ground rules for building LCA, while EN 15804 establishes one for building products. Both norms refine the framework given by the ISO norms and give instructions and rules for conducting an LCA. One example of this refinement is the establishment of the life cycle phases of buildings and building products, as seen in Figure 2-5. The product stage (Modules A1 to A3) includes the extraction of raw materials (A1), transportation to the manufacturing site (A2), and the actual manufacturing processes (A3). The construction process stage (Module A4 - A5) encompasses the transport to the construction site and the construction/installation of the building product. The use stage (Modules B1 to B7), the building product's usage, repair, maintenance, and operational energy and water demand are evaluated. The end-of-life stage (Modules C1 to C4) covers the deconstruction/demolition of the building product, transport to waste processing, waste processing itself, and final disposal. Potential benefits and loads beyond the system boundary can be reported in Modul D. These are additional environmental impacts related to the reuse, recovery, or recycling of materials. (Achenbach et al., 2018)

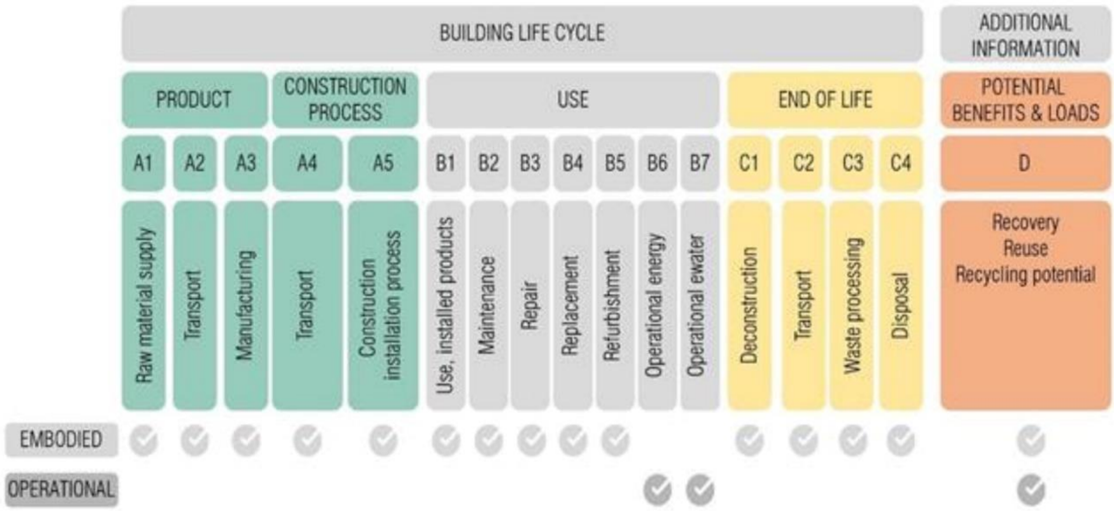



**Figure 2-5: Different Phases of an LCA according to EN 15978. (Giordano et al., 2021)**

However, none of these standards explicitly outlines specific conventions or regulations for building LCAs, such as defining system boundaries, determining the duration of the study period, or establishing cut-off criteria (E. P. Schneider-Marin, 2022).

Another indicator showcasing the importance of LCA is the implementation of LCA as part of major sustainable building certifications like Building Research Establishment Environmental Assessment Method (BREEAM), Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), and Leadership in Energy and Environmental Design (LEED) (Anand & Amor, 2017). In LEED, credits can be earned to reach a specific certification level by conducting a whole building LCA and using products with environmental product declarations (EPD) (U.S. Green Building Council, 2013). Similarly, the DGNB certification awards points for conducting an LCA and grades the actual environmental impact of the building compared to a base case. However, this is only possible as the DGNB defines more detailed rules than the EU norms on how an LCA should be conducted. This includes, but is not limited to, a defined length of the study period of 50 years, cut-off criteria, and system boundaries (e.g., included building parts, including life cycle phases), enabling a comparison of the results between buildings and enabling the DGNB to rate the building following predefined benchmarks. (DGNB, 2023). An overview of further challenges and limitations regarding LCAs can be found in Chapter 2.2.2.4.

Figure 2-6 gives an overview of areas where LCA is applied in the building industry. For this paper, the area of EPDs and LCAs for non-residential buildings is essential.

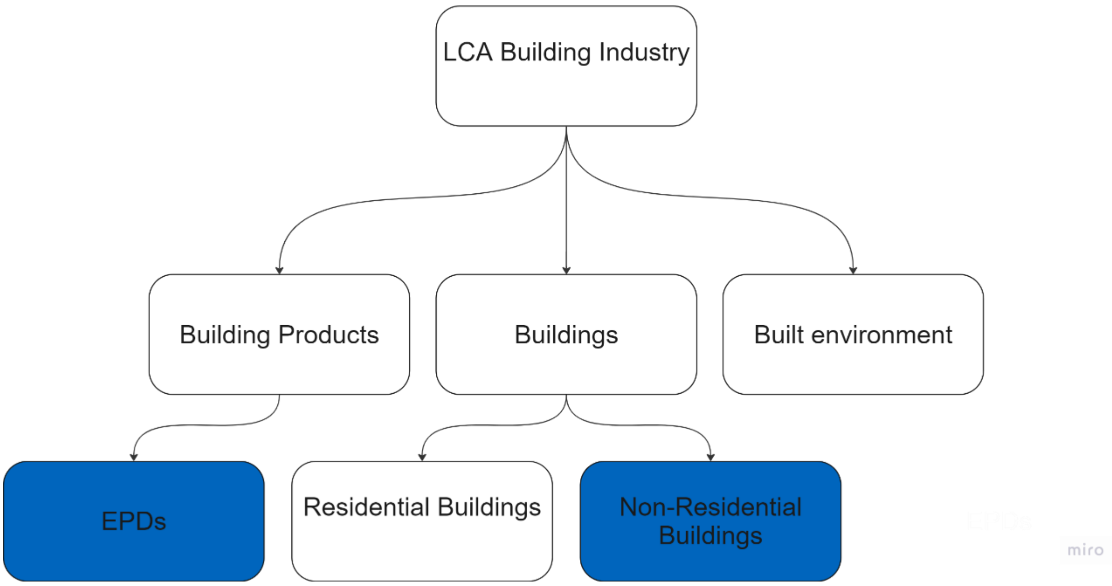



**Figure 2-6: Overview of areas of the building industry where the LCA method is applied (Goldstein & Rasmussen, 2018; Weißenberger, 2016)**

### 2.2.2.1 Environmental Product Declarations for Building Products

EPDs are documents that provide quantified environmental data for a product over its life cycle and are the results of an LCA of parts or the entire life cycle of a product. These documents are third-party verified and follow specific product category rules (PCR). These PCRs include information that has to be found in the EPD. (Pichette et al., 2023) This includes rules that must be met for the LCA of any product in the category to ensure a comparison between similar products that are part of a PCR. (Gelowitz & McArthur, 2017) Though EPDs do not validate the environmental friendliness of a product, they enable stakeholders to pinpoint emission-heavy processes in the manufacturing process of the product or compare two products of the same category, e.g., insulation materials, and select the one product that is less environmentally harmful (Hauschild et al., 2018).

In the EU, EPDs for building products follow the norm EN 15804. The most important parts it governs are which life stages must be included in the analysis, namely A1-A3, C1-C3, and D, and which impact category must be part of the analysis. Furthermore, it defines the data quality for the underlying LCA, thereby ensuring transparency and comparability. In February 2020, the new standard EN 15804+A2 was introduced, and comprehensive changes were made to impact indicators of EPDs. Table 4 lists the new impact categories. In general, the old indicators were expanded / diversified.

(Rasmussen et al., 2021) However, as many EPDs from the old standard are still valid, understanding the differences is important.

**Table 4: Overview of the expanded indicators in EN 15804 (Rasmussen et al., 2021).**

| Indicators according to EN 15804+A1 | Indicators according to EN 15804+A2 | Units |
|---|---|---|
| Global Warming Potential | Climate Change Total | kg CO2-eq. |
| --- | Climate Change Fossil | kg CO2-eq. |
| --- | Climate Change Biogenic Removals and Emissions | kg CO2-eq. |
| --- | Climate Change Land Use and Land Use Change | kg CO2-eq. |
| Depletion of Stratospheric Ozone | Ozone Depletion | kg CFC-11-eq. |
| Acidification | Acidification | kg SO2-eq. |
| Eutrophication | Eutrophication Aquatic Freshwater | kg P-eq. |
| --- | Eutrophication Fresh Marine | kg N-eq. |
| --- | Eutrophication Terrestrial | mol N-eq. |
| Photochemical Ozone Formation | Photochemical Ozone Formation | kg NMVOC-eq. |
| Abiotic depletion of Fossil (resources) | Abiotic Depletion- Minerals and Metals | kg Sb eq. |
| --- | Fossil Fuels | MJ |
| --- | Water Use | $m^3$ |

EPDs are helpful in the construction sector as they function as building blocks, relieving practitioners of the LCA of a building from the need to detail the manufacturing process of each building material (E. P. Schneider-Marin, 2022). Generally, EPDs can be differentiated between generic, average, and specific types. Generic EPDs rely on publicly available statistics and other literature sources. Average datasets rely on industry-wide average data, such as the German cement industry, and product-specific EPDs estimate the environmental impact of a specific product from a specific production facility or company. (Gantner et al., 2018)

### 2.2.2.2 System Boundaries for LCA in the Building Industry

Though the norms establish a base framework for an LCA in the building industry, whole-building LCAs are not part of the current design process as mandated by governmental rules (E. P. Schneider-Marin, 2022). Therefore, no general system boundaries have been defined, and the study's authors are responsible for them. In the literature, different definitions were identified. For the temporal component, mainly the reference study period, the most common time frames range from 30 – 100 years. Weißenberger (2016) analysed 21 case studies and multiple metastudies and found that 43% used a reference study period of 50 years. Figure 2-7 shows the distribution of all reference study periods he encountered.

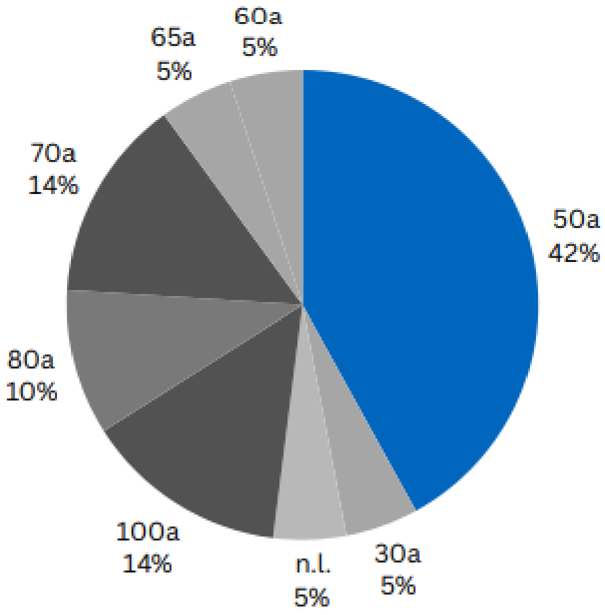



**Figure 2-7: Overview of the reference study periods mainly used in buildings LCA. a= years, n.I.= no Information (adapted from Weißenberger, 2016)**

Izaola et al. (2022) and E. P. Schneider-Marin (2022) agree with this assessment that 50 years are the most commonly used reference study period but highlight that longer study periods emphasise the use phase, while shorter periods prioritise the initial and final phases of a building's life cycle. The selected duration of the study should follow the objectives and scope, taking into account key features of the building, like its function and construction quality. Furthermore, Germany's two main certification systems, DGNB and BNB, use a 50-year reference study period (DGNB, 2023). Building components also have an estimated lifetime, but these are pre-set in the used program eLCA. These pre-set service lives of building components are defined by the "Bundesinstitut für Bau-, Stadt-und Raumforschung" (Federal Institute for Research on Building, Urban Affairs and Spatial Development, BBSR) in their published BNB service life of components document from 2017 (BBSR, 2017).

The spatial system boundaries include the LCA stages, functional units, and construction components. Izaola et al. (2022) compared the spatial system boundaries of European building certification programs. Table 5 shows the results of his findings.

**Table 5: Different spatial system boundaries of building certification systems in Europe. (Izaola et al., 2022)**

| Building Certification Name and Country | Indicator Code/Name | Stages | Impact Categories | Building Elements |
|---|---|---|---|---|
| NF Habitat: France (HQE) | Indicators PE1.4.4, RCE4.1, REM2.4.1, DEC1, and DEC2 | N/A | Related to the indicators | Potentially any |
| VERDE: Spain (GBCe) | RN 11 Impacto de los materiales de construcción | A1, A2, A3, A4, A5, B4, C3, C4 | GWP, ADP, AP, EP, POCP, ODP | Envelope, inner partitions |
| DGNB-System International 2020 for buildings: Germany (DGNB) | Building life cycle assessment (ENV1.1) | A1, A2, A3, B2, B4, B6, B7, C3, C4, D | All Impacts | All |
| BREEAM NL: The Netherlands (DGBC) | MAT1: material specification | A1, A2, A3, product-based | GWP | At least three materials |
| HPI: Ireland (IGBC) | EN:7.0 embodied impacts of homes and LCA, plus exemplary points | A1, A2, A3, A4, A5 | GWP, ODP, AP, EP, or POCP as possible | Whole building |

It highlights the differences in spatial system boundaries even though they all are within the framework of the EU norms. Similar observations for the included stages were observed in the 21 analysed case studies by Weißenberger (2016). Though all included A1-A3, only 76% included Phases B2-B5 and C3-C4. Although the operational energy demand (Stage B6) was included in all cases, the basis of the calculation differed as different energy demands were included or excluded, e.g., household electricity demand. In the DGNB certification system, Phase B6 includes all energy demand that is part of the German Energy Pass according to the "Gebäudeenergie Gesetz" (German Building Energy Act, GEG) (DGNB, 2023). Lastly, Module D is only included in one certification system. The inclusion of Module D in the LCA of buildings is often viewed critically due to the uncertainties associated with the end-of-life phase of building materials. The nature of end-of-life processes is highly uncertain, as the fate of building materials can vary based on future technological advancements, regulatory changes, and market conditions. This uncertainty can significantly influence LCA results, making it difficult to predict the precise environmental impacts of materials post-demolition (Sandin et al., 2014). Additionally, methodological choices and assumptions, such as the type of waste treatment (e.g., recycling versus incineration) and selective demolition practices, can lead to considerable variations in the outcomes of LCAs (Vitale et al., 2017)

The functional unit for the LCA also differs in the literature. The DGNB and BNB suggest that besides the reference study period, the functional unit should include the net floor area in m² defined after DIN 277 (BBSR, 2015b; DGNB, 2023). Generally, geometry-based functional units are common, but newer publications suggest including user-centred functional units to highlight the per capita floor area increases in developed countries (E. P. Schneider-Marin, 2022).

In Germany, building components are structured after their CG as defined in DIN 276. Table 6 shows the different CGs and their subgroups defined after DIN 276 and whether they are included after the certification systems BNB (BBSR, 2015a) and DGNB (DGNB, 2023), and the publications by König (2017), E. P. Schneider-Marin (2022), and Weißenberger (2016).

**Table 6: Overview of the different CGs included in the LCA Methodologies. CGs marked with an x/(x) are included / partially included.**

| Cost Group | Cost Sub Group | Subgroup Description | BNB (2015) | DGNB (2023) | König (2017) | Schneider-Marin (2022) | Weißenberg (2016) |
|---|---|---|---|---|---|---|---|
| 300 | Building - Construction | | | | | | |
| | 310 | Excavation | | | | | |
| | 320 | Foundation | x | x | x | x | x |
| | 330 | Exterior walls | x | x | x | x | x |
| | 340 | Interior walls | x | x | x | x | x |
| | 350 | Ceilings | x | x | x | x | x |
| | 360 | Roofs | x | x | x | x | x |
| | 370 | Structural installations | | x | | | |
| 400 | Building - Technical installations | | | | | | |
| | 410 | Sewage, water and gas systems | x | x | x | x | x |
| | 420 | Heating systems | x | x | x | x | x |
| | 430 | Air conditioning systems | (x) | x | x | x | x |
| | 440 | Power installations | | (x) | x | x | x |
| | 450 | Telecommunications and information technology systems | | x | x | | x |
| | 460 | Conveyor systems | (x) | x | | | x |
| | 470 | Usage-specific and process engineering systems | | x | | | |
| | 480 | Building and plant automation | | x | | | |
| | 490 | Other measures for technical systems | | | | | |
| 500 | outdoor facilities | | | | | | |
| | | Building constructions in outdoor areas | x | | | | |
| | | Technical installations in outdoor facilities | (x) | | | | |

Note that in each certification system and publication, the cost sub-groups 310-360 are included, as well as 410 – 430.

In summary, system boundaries differ across all major certification systems in Germany and publications, and therefore, a clear trend can not always be identified. Furthermore, some boundaries must be adjusted to fulfil the goal and scoop definitions of the LCA. However, a transparent presentation of the system boundaries is crucial for comprehensibility and, consequently, for the transferability of results.

#### 2.2.2.3 eLCA & ÖKOBAUDAT

For this analysis, the software eLCA in version 0.9.7 is used. The BNB developed the tool to create a free tool that planners could use to conduct an LCA for the sustainable building certification “Bewertungssystem nachaltiges Bauen” (Assessment system for sustainable building, BNB). The BNB is a certification program for planning and evaluating the sustainability of building projects in Germany, generally public buildings. ELCA helps practitioners link the building's material quantities to EPDs and calculate the resulting emissions. (Figl et al., 2017)

ELCA accesses the Ökobaudat database, which the BBSR also manages. Ökobaudat is the first database that fully complies with the DIN EN 15804 standard. The database provides EPDs sorted into three categories (A, B, C) to ensure data consistency. Category A data consists of life cycle assessment data from environmental product declarations (EPDs) that adhere to DIN EN 15804 standards. These EPDs are part of a program operating under DIN EN ISO 14025, with program instructions and product category rules available to the public and compiled according to DIN EN 15804 and DIN EN ISO 14025. (Figl et al., 2017)

Category B data, on the other hand, includes verified EPDs or LCA data complying with EN 15804 but not generated within a DIN EN ISO 14025-compliant EPD program (Category B1) or not published as part of an EPD (Category B2). Despite this, Category B data undergoes external verification or critical review similar to Category A data. Coordination with the ÖKOBAUDAT Users’ Advisory Group is necessary for submitting Category B data, ensuring compliance with DIN EN 15804 through external verification or critical review. (Figl et al., 2017)

Category C data, or "generic datasets," is based on DIN EN 15804 but lacks external review by an independent third party. This data may include replacement data provided by ÖKOBAUDAT for product categories lacking Category A or B data. Safety margins of 10% to 30% are applied during data generation. The BBSR commissions necessary generic datasets, and while some datasets are verified internally by the supplier, others undergo external critical review. Category C data not commissioned by the BBSR is not included in ÖKOBAUDAT. (Figl et al., 2017)

The most recent amendment, EN 15804+A2, was published to replace EN 15804+A1. Impact indicators calculated according to the new standard cannot be compared with those of the old DIN EN 15804+A1 and should not be used together. Therefore, datasets compliant with DIN EN 15804+A2 are displayed in a separate ÖKOBAUDAT database. However, this change led to complications regarding data availability for many building products used within this analysis, such as the dataset used, the OBD_2023_I_A2. (BBSR, 2021)

Though the ÖKOBAUDAT is one of Europe's leading EPD databases, further shortcomings have been identified. In the ÖKOBAUDAT, technological advances for generic datasets are considered insufficient. On the one hand, this refers to changes in the background system, like improvements in the electricity mix used to produce a product. On the other hand, changes in the foreground system (advances in developing product-specific technologies) can also affect the environmental impact of products. This includes, for example, a higher efficiency in the production of a product or a significant change in production location. A good example of this is the production of photovoltaic modules. Furthermore, generic datasets for common building materials and HVAC systems are missing, or only insufficient options are available. (Gantner et al., 2018)

Similar shortcomings could be observed in this analysis. See further information in chapter 3.3.2.

#### 2.2.2.4 Challenges and Limitations of LCA in the Building Industry

As LCA in the building industry becomes more common, different challenges and limitations have been identified. E. P. Schneider-Marin (2022) highlights that Building LCA differs from consumer product LCAs in the following and makes them, therefore, more complex:

- Buildings are unique, and therefore, each building needs its own LCA
- Buildings consist of a lot of different products rather than a small number of raw materials
- Each building is built at a different location, and the corresponding site-related processes like transportation and construction processes differ
- Building life cycles are usually longer than product life cycles

In the study conducted by Anand and Amor (2017), different challenges and limitations of LCAs in the building industry were identified and allocated to functional units, system boundaries, LCI, and LCIA. In the case of the functional units, the different definitions of a functional unit made comparing the results of different LCAs difficult or impossible. Furthermore, a lack of reliable information regarding the calculated service life of a building can lead to different results regarding the influence of operational emissions and the impact of refurbishments in a building. In general, the lack of a clear method or rules to determine the system boundaries is a major challenge to comparing results and underlies the subjective choices of the practitioner. Variations in LCI stemming from different sources like the building industry, databases, or EPD, as well as differences in data age and collection methods, impact decision-making and comparability in building LCAs. The lack of standardised data collection methods and insufficient guidance from current standards exacerbate these issues, making it challenging to ensure data quality and requiring urgent development of standardised methodologies and data quality checks. In building LCA studies, while energy demand and GWP are commonly analysed as impact categories, they may not always be the most impactful on the environment. The selection of impact categories often lacks clarity and standardisation, resulting in essential impacts being overlooked due to stakeholder preferences or tool limitations.

Furthermore, different LCA studies highlight the lack of data or accessibility to data to correctly display the emissions of the building materials used in the construction and highlight that the results can only be as robust as the underlying data (Dascalaki et al., 2020; Martinopoulos, 2020b; Weißenberger, 2016). This challenge remains even if databases like ÖKOBAUDAT are available (cf. chapter 3.3.2).

## 2.3 Energy Simulation

Energy simulations are an established method to predict the operational energy demand of a building. They can be used to optimise building parameters or as input to estimate the operational emissions for the LCA in stage B6. For the simulations, different parameters are divided into technical information, like HVAC configurations, geometry, and thermal characteristics of the building hull; climate data information, like temperature and wind; and non-technical data, like occupancy, clothing, and user behaviour, which are important. (Kampelis et al., 2020) Similar to LCA, the definition of system boundaries is critical in simulation studies. For instance, it is important to determine whether the surrounding geometry of a building, including elements such as trees or neighbouring buildings, is considered for shading effects. Additionally, specifying which internal loads, such as heat gain from occupants, are included.

This chapter will explore static and dynamic calculation methods, discuss the simulation performance gap, and describe how to validate these simulations to ensure accuracy and reliability in energy performance assessments.

### 2.3.1 Quasi-steady-state Simulations

Quasi-steady-state building energy simulations (QSS) are simplified methods used to estimate the energy demand of buildings. They typically involve monthly calculations and consider basic factors like geometry and infiltration. (Dalla Mora et al., 2021) In Germany, the GEG regulates how the energy demand of a building has to be calculated to ensure comparability of results and limit the energy demand of a building compared to a benchmark building. Normally, a QQS is required after DIN V 18599: 2018-0, but it allows the performance of a dynamic energy simulation in special circumstances. Furthermore, it defines system boundaries for the simulation, excluding the demand for electrical user applications. (GEG, 2020/10/16/2023) This method assumes that boundary conditions remain constant over each calendar month, using averaged conditions. The heating demand is calculated monthly, assuming constant outdoor temperatures depending on the climate date. This leads to steady heat flows through building components, with fixed transmission and ventilation heat losses. Solar and internal gains are also treated as constant over the month. Transitions between months are abrupt, and thermal storage capacity is accounted for using generalised factors, not dynamic calculations. Relevant climate data are provided in DIN 18599-10:2018-09 for selected locations in Germany. (DIN, 2018)

The Dalla Mora et al. (2021) study demonstrates that the QSS method accurately predicts building energy demand, comparable to results from two dynamic energy simulation tools when only geometry and infiltrations are considered inputs. However, its limitations become apparent with the introduction of internal loads, leading to a significant underestimation of energy demand. This makes it a tool to estimate energy demand in the early design stages.

### 2.3.2 Dynamic Energy Simulation

The literature differentiates between two types of dynamic energy simulations: white box (physical model) and black box (data-driven) (Kampelis et al., 2020; Zhao & Magoulès, 2012). In a white box model, a physical model is developed to evaluate energy consumption based on heat and mass transfer equations between the building and the surrounding environment. These physical models can be broken down into single zones or multi-zone models. The environment is considered homogeneous inside one zone, meaning that variables like temperature, pressure, and relative humidity are the same. Heat transfer equations are calculated at these zones' convergence depending on the specific load, building elements, and HVAC systems. This approach proves highly efficient for assessing the energy performance of buildings with numerous thermal zones, as it requires relatively little computational time for year-round simulations and is therefore suitable for examining the effect of various energy efficiency measures of a building. (Kampelis et al., 2020) Further advantages are that certain outputs, e.g., room temperature, can be evaluated for each room/zone for different time steps (hours, days, months, years), and no training data for the model is required. (Krstić & Teni, 2017) Prominent white box engines for energy simulation are Energy Plus, TRNSYS, and IDA-ICE (Shahcheraghian et al., 2024).

A black box model, called data-driven modelling, feeds real/observed data into an algorithm to predict future energy consumption and behaviour. Data-driven techniques are often categorised by the type of statistical models they use (e.g., Support Vector Machines, Artificial Neural Networks), the nature of the data (empirical or pre-simulated), and the specific variables they predict. One major advantage of data-driven models in building applications is that they do not require detailed knowledge of the building's physical properties. By analysing input data like weather conditions and occupant behaviour and output data such as energy usage, these models can reveal underlying patterns and relationships without the need for complex physical equations. (Shahcheraghian et al., 2024) Further advantages are that besides the required training data, the actual model development is short as only a limited amount of input data is required (Krstić & Teni, 2017).

In general, in a white box model, all governing principles are known, allowing for explicit modelling of the relation between input and output, whereas, in the black box model, the relation between input and output is based on machine learning that captures the correlation by learning from correlated data pairs without any knowledge of the internal workings of the system that causes this correlation. Both models use dynamic data, such as weather data. They can calculate the energy demand or temperature hourly or even each second of a day, depending on the changing environment, like shadows or the sun's position. Therefore, the results have a higher resolution than a static simulation and can reveal more details. (Wilde, 2018)

### 2.3.3 Energy Performance Gap

Though energy simulations are an important tool to assess the energy demand of a building, the actual (measured, observed, or monitored) performance of a building can be worse. This energy performance gap (EPG) is defined in the literature as the difference between simulated and actual energy demand. (Li et al., 2023; Menezes et al., 2012; Wilde, 2014). Reducing this discrepancy is crucial as most building standards, like the GEG in Germany or the EPBD in the EU, regulate and evaluate the environmental sustainability of a building based on the predicted operational energy demand. This is important as higher energy demand leads to more emissions in the current energy mix. The magnitude observed of the EPG differs between the building types, e.g., office buildings, residential buildings, and school buildings, and can be between 20 – 550% more energy demand than the simulation predicted. This range of values shows, on the one hand, the significance of the EPG and hints that there are multiple reasons for this discrepancy resulting in such a wide range. (Li et al., 2023) According to a study conducted by van Dronkelaar et al. (2016), the average EPG of a building is +34%, which could significantly affect the LCE performance evaluation.

Wilde's (2014) classification of the reasons for an EPG, the design stage, construction stage, and operational stage, is used to give a better overview of the different reasons for this deviation in performance. During the design stage, miscommunication between the simulation operator and the planning team or plan discrepancies can misrepresent the building. Furthermore, necessary simplifications of a model can lead to a lack of appropriate detail, which can further reduce the model's accuracy. (Wilde, 2014) Also, assumptions of important input parameters like the assumed room temperature can further deviate results (Cozza et al., 2021).

In the construction phase, the quality of the air tightness and insulation performance can heavily influence the energy performance of a building, and the lack of a good handover process of important technical information after the completion of the construction phase reduces the effectiveness of the HVAC system (Li et al., 2023). During the operational stage of the building, three main reasons for the EPG were identified. The first is a malfunction or underperformance of the technical equipment in the building, like the heating system, which leads to a worse performance than simulated (Cozza et al., 2021). The most often cited reason for the EPG is occupancy behaviour. This can be divided into wrongly simulating the occupancy behaviour, for example, assuming the user turns off the lights once sufficient daylight is available, misusing technical equipment, or misunderstanding the technical functions. A good example is opening the windows even though the room is mechanically ventilated, which leads to heat losses. (Li et al., 2023) Lastly, a lack of post-occupancy monitoring and optimisation of the buildings and user behaviour wastes the potential to reach the simulated performance (Kuwabara et al., 2013; Li et al., 2023).

As the reasons for the EPG are manifold, so are the solutions. Zou et al. (2019) suggest methods for most reasons mentioned. For once, he suggests improving the communication between planners by introducing feedback loops to reduce undocumented changes during the design process. Furthermore, machine learning, data from similar buildings, and occupation and nonoccupation hours can reduce the discrepancy between the inputs and the actual building. Post–occupancy monitoring and information campaigns for the users further reduce the EPG and can even lead to overperformance. On the other hand, (Nagler, 2022) introduces a different approach. He suggests that robust technical building equipment is necessary to reduce the EPG. Robust in the sense that the technical building equipment is resistant to operational failures, user errors, and climate change. This can be reached by implementing quality assurance measures during commissioning and building operations and by limiting the technological sophistication of the technical building equipment by following the concept of “As much technology as necessary and as little as possible”. (Nagler, 2022)

In conclusion, energy simulations are a vital tool to estimate the energy demand of a building and corresponding operational emissions during the lifetime of a building. However, the results of these simulations are only as accurate as the input data, the simplification of the building design, and its handling by users. Simulation outcomes should be compared with actual building operations to achieve better results.

### 2.3.4 Validation of Energy Simulation

There are three types of validation: analytical, logical, and empirical. These differ mainly in terms of their data basis and applicability. Analytical validation involves performing an exact, analytical solution for a calculation and comparing the result with the model. This method is only applicable when an exact solution to a problem can be provided, typically for simple test cases. It is often used in model development to verify if individual parts of a model are correctly implemented. However, it is unsuitable for validating combined parts and a complete model due to the lack of exact solutions. (Ryan & Sanquist, 2012)

Empirical validation compares the result of the model with real, measured data. These data must be collected under known boundary conditions that can also be represented in the model, usually achieved through expensive and complex experiments. This method is considered the "gold standard" for accurately representing reality in a model. (Ryan & Sanquist, 2012) One method to compare real data with simulation results is by examining the energy bills of the building after the completion and monitoring/adjustment phase. Alternatively, room temperature data can be measured and compared with the simulation outcomes.

Logical validation involves comparing the model’s results with those of other models, assuming the correctness and validation of the comparison models. However, it is impossible to investigate and validate all combinations of parameters and all applications of a simulation model. Therefore, validations often occur under idealised conditions, neglecting user behaviour and considering an imaginary test space. These test spaces can also exist in reality and provide comparative data through measurements. Validation under realistic conditions considers user behaviour and applies the model to real existing buildings. (Ryan & Sanquist, 2012) This approach is used to validate the case study's energy simulation as the actual building's original energy simulation is available.

## 2.4 Concepts Evaluating Future Emissions

Part of this analysis are two concepts, the time value of carbon and the inclusion of a decarbonising energy grid, which influences the results of comparing OE and EE. As both concepts underly certain data uncertainties and assumptions for the future, they can lead to an unfair comparison of the results. However, they both showcase the complexity of comparing future emissions and emissions from today.

### 2.4.1 Time Value of Carbon

The concept of a time value for carbon emissions or other greenhouse gases is the idea that there is a greater benefit to reducing the same amount of emissions today than reducing it in the future (Strain, 2017). It is based on the assumption that GHGs remain in the atmosphere for a long period. Therefore, the cumulative damage of these GHGs on the environment is significant as they increase the frequency of extreme weather events and affect infrastructure, agriculture, overall economic stability, and human health. (Davis et al., 2010; Wahba & Hope, 2006) Furthermore, only limited time remains to avert reaching climate tipping points, which makes it vital to reduce climate emissions now rather than later (Lewis et al., n.d [2022]. Climate tipping points are elements of the Earth system in which small changes can kick off reinforcing loops that 'tip' a system from one stable state into a profoundly different state (ESA, 2023).

One way to weigh these damages over different periods is through the social costs of carbon (SCC). SCCs are calculated by integrated assessment models like the "dynamic integrated climate-economy model" or the "policy analysis of greenhouse effect model". They link a global economic model and a global climate model along an emission scenario and simulate the expected damages due to the increase in GHGs at a certain point in time. Future damages are converted into a present value by using a discount rate. Economic discounting involves translating the worth of a future value into its present-day equivalent. For instance, a dollar obtained in 50 years might be considered less valuable than a dollar acquired today; discounting is used to weigh this difference in value. (Resources for the Future & New york State Energy Research and Development Authority, 2020) A benefit of this discounting process to a net present value is whether a certain choice leads to an overall net benefit (National Academies of Sciences, 2017). For example, is it better to reduce the GHGs during the operational period of a building even though the EC in the construction materials rises?

However, the literature differs in estimating this discount rate for SCC as incremental changes can already have big impacts as the periods observed are usually long, and because weighing off between the damages for future generations and the benefits of the current generation becomes an ethical question. (Cai & Lontzek, 2019; Löffler, 2021; Parisa et al., 2022; Resources for the Future & New york State Energy Research and Development Authority, 2020; Sarofim & Giordano, 2018).

For this paper, the discount rate of 1% of the Umweltbundesamt (German Federal Environmental Agency, Umwelt Bundesamt, 2020) and a discount rate of 2.5%, which is the variation range used by P. Schneider-Marin and Lang (2022), are implemented.

According to (Brealey et al., 2009) the discounting process follows the formula:.

$$Net\ Presenet\ Value = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

Where

- $C_t$ represents the cashflow at the time t
- r the discount rate
- t the specific time in the future in years

- n the number of years of the investment period

For simplification, the cash flow represents the number of GHGs emitted or prevented during the use phase B of the building, and n equals 50 years, the same as the estimated building life for the LCA. Figure 2-8 shows the development of the present value of 1 kg of CO2-Equ. Emissions for 50 years if they are discounted with the two discount rates.

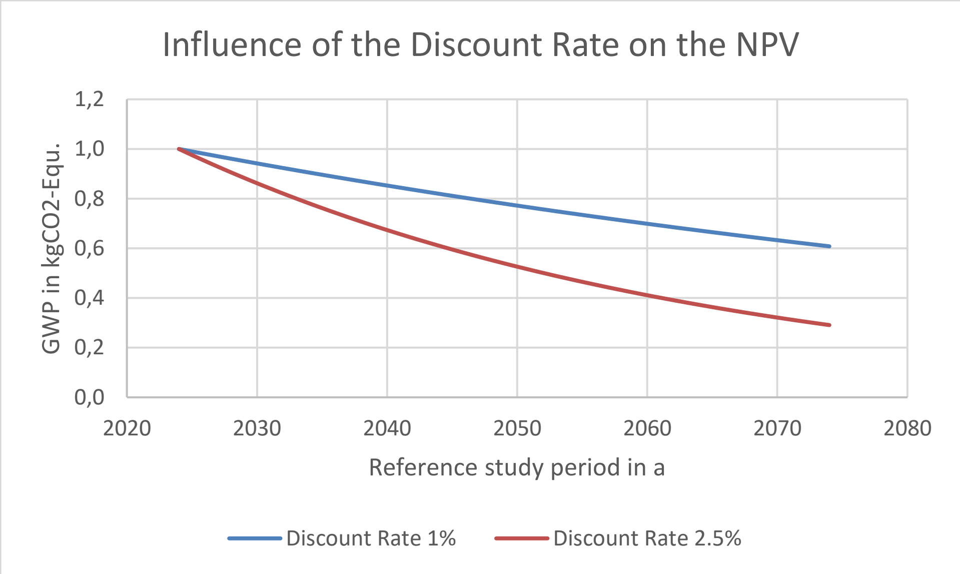



**Figure 2-8: Development of the NPV of 1 kg CO2-Equ. emissions with a discount rate of 1% and 2.5%.**

Depending on the discount rate, the NPV of 1kg CO2-Equ. Emissions decrease by 40% in a scenario with a discount rate of 1% and by 74% in a scenario with a discount rate of 2.5%. This highlights, on the one hand, the impact of discounting and, on the other hand, how much influence a change in the discount rate has.

### 2.4.2 Decarbonisation of the Energy Grid

The second concept deals with considering the decarbonisation of the energy grid. Two factors influence the total emitted OE of a building. The first is the energy the building needs during the life cycle, which can be assessed and optimised in an energy simulation. The second factor is the energy mix provided by the grid at the location of the building. As the building lifetime is generally assumed to be around 50 years or more, the impact of these changes should be considered in an LCA. However, current rulings or certification programs consider only today's energy mix (BBSR, 2015b; DGNB, 2023).

For instance, in Germany, the GWP per year of the electricity mix has been reduced by 40% from 1990 to 2021 and is expected to be further reduced by 83% from 2019 to 2050, showing the importance of the dynamic decarbonisation of the electricity mix for an LCA (Harthan et al., 2023; Umwelt Bundesamt, 2022). Furthermore, Kiss et al. (2020) showed that if the EU targets for the electrical mix in Hungary are reached and are then taken into account, the total GWP of 1 MWh of electricity would be reduced by 83% in the year 2050, which would still be well in the timeframe of the operational stage of a building. Ramon and Allacker (2021) and Ayagapin et al. (2021) also recognised this development's significance and incorporated the energy sector's decarbonisation into their dynamic LCAs. Ramon and Allacker (2021) found that depending on the underlying scenarios, the GWP of the entire building life cycle can vary between -59% to + 33%, while Ayagapin et al. (2021) observed a 45% reduction.

Therefore, this paper will take one analysis of the decarbonisation of the German energy grid into account, focusing on electricity production as the case study building only uses electricity as the primary energy carrier (cf. 3.1.1.) Two different decarbonisation scenarios will be compared: In the optimistic one, the targets for 2030 and 2045 of the federal government are met. This means a reduction of 85% in CO2 emissions in electricity production by 2030 compared to 2020 and a further reduction of 100% by 2045 compared to 2020. (Luderer et al., 2021) The second scenario assumes a linear reduction of CO2 emissions that reaches zero in 2045. Figure 2-9 shows the three decarbonisation scenarios for the German electricity mix used in this analysis.

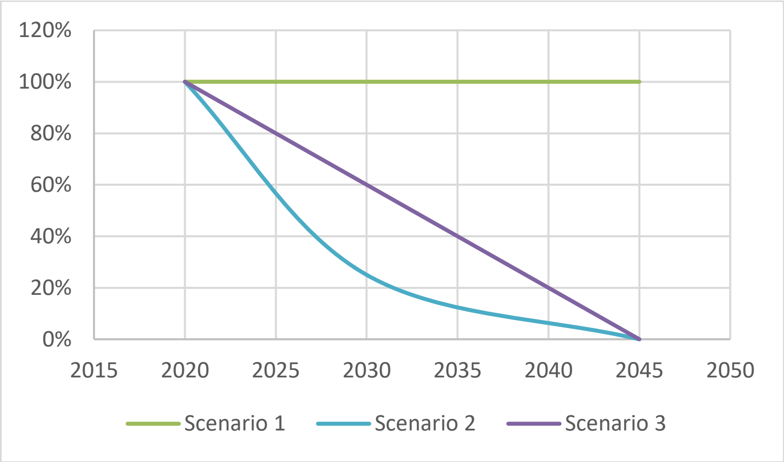



**Figure 2-9: Different decarbonisation scenarios for the German electricity mix.**

# 3 Approach and Methodology

In this chapter, the methodological approach of this thesis is explained. Furthermore, the base case on which this analysis is built is introduced in detail, and the framework conditions of the LCA and Energy simulations are defined.

## 3.1 Methodology

This master's thesis employs a systematic approach to assess the sustainability of a refurbishment of a school building in Stuttgart compared to different variants where different design decisions are altered. In Figure 3-1, the overall methodological approach is shown.

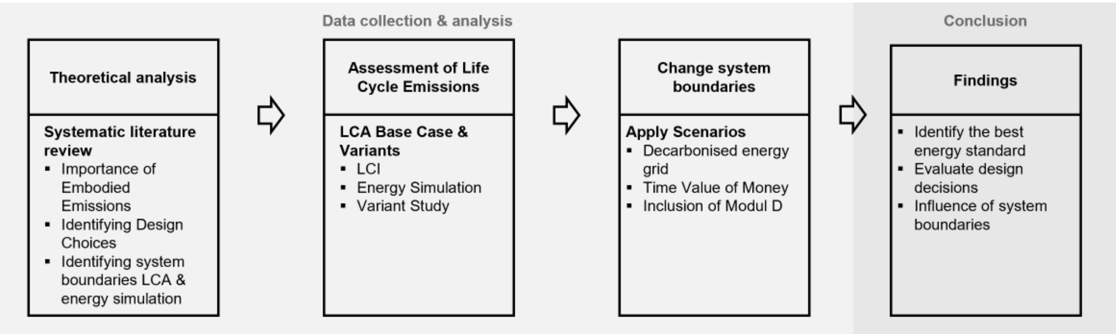



**Figure 3-1: Methodological approach of this thesis.**

The basis for the LCA is an extensive literature review that identifies the importance of EE, which design decisions influence the LCE, the system boundaries for the LCA, and the energy simulations (cf. Chapter 2). This involves examining relevant literature to establish key boundaries (e.g., timeframe, LCA phases & module D, performance gap of buildings) and secure data consistency and quality.

In the next step, the LCE of the base case and the variants are assessed. For this, the quantities of used materials are estimated and documented in the LCI. With the help of the software “eLCA”, environmental impacts are calculated, focusing on the global warming potential. In addition, the method developed by the “Qualitätssiegel Nachhaltiges Bauen” (Quality seal for sustainable buildings, QNG) is used to calculate parts of the impact of the technical building equipment. If necessary, external EPDs will be used to calculate the emissions of construction materials unavailable in “eLCA”. Simultaneously, an energy simulation is conducted to estimate the energy demand of the base case and the variants. These energy demands are the inputs for Module B6 of the LCA. Overall, this step involves the analysis of various design variants of the building to assess their impact on energy usage and, ultimately, emissions. Integrating the energy simulation results into the LCA shows the relationship between OE, EE and the overall effect on the LCE. This way, the research seeks to identify synergies and trade-offs between the different building variants regarding the LCE and answer the research question. Figure 3-2 shows the flow of information in the second step.

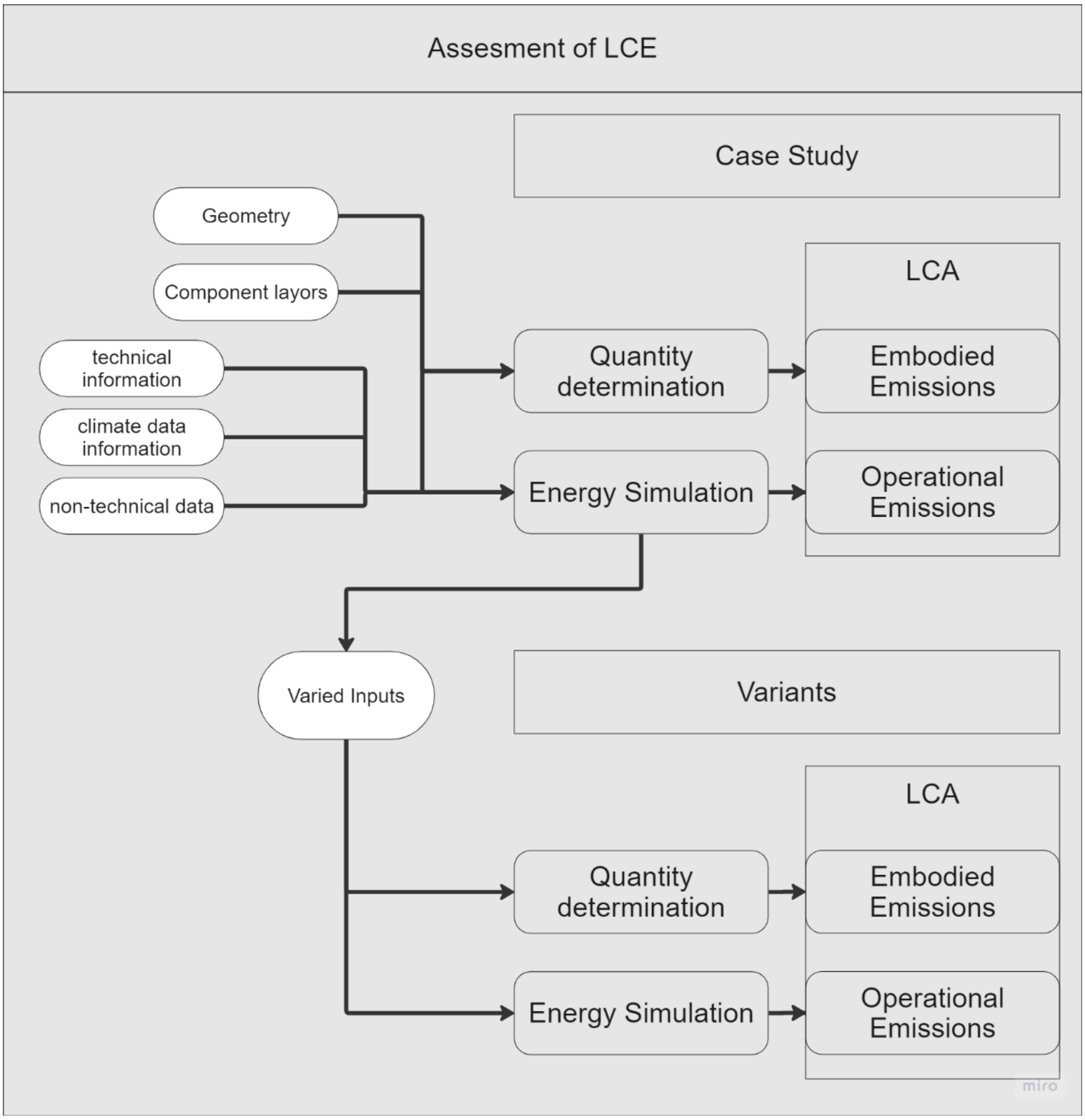



**Figure 3-2: Flow chart of the overall methodological approach of the analysis.**

Lastly, the development of the LCE under different scenarios is analysed. These scenarios are based on the decarbonisation of the electricity grid, the time value of carbon emissions and the expansion of the system boundaries to include Modul D. To ensure the robustness of the study, sensitivity analyses are performed, evaluating the influence of the performance gap of the building by varying the results of the building energy simulation by +34%.

Ultimately, the research tries to show whether an energy-plus building is the right design standard for optimising the sustainability of refurbished school buildings or if different design decisions can lead to an overall better performance regarding the LCE. Drawing on the insights from LCA and energy simulation, the thesis lays the basis for practical guidance for future projects, enabling informed decision-making in sustainable building design.

# 3.2 Case Study and Variants

At the core of this analysis is assessing the amount of GWP of the major modernisation of the Uhlandschule Rot in Stuttgart, Germany, and whether different design choices and lower energy standards could have achieved better carbon performances. This chapter gives a short overview of the modernisations that were conducted. Furthermore, it lists the different alternative energy standards and design choices considered and why these are part of the analysis.


**Figure 3-3: Uhland school building. View from the South East on the façade after the finished refurbishments. (Uhlandschule Zuffenhausen-Rot, n.d.)**

## 3.2.1 Case Study: "Uhland Schule Rot, Stuttgart"

The information used in this chapter has been compiled from the booklet about the modernisation of the school (Wenger, 2018), architectural plans, and building documents like the energy pass and the HVAC descriptions. The documents were provided for a research project at the Technical University of Munich.

The original Uhland school building was built in 1954 and consists of a main building with an extension and a secondary building from 2004. It is used for primary and secondary education and can house up to 450 students. The entire complex was modernised as an energy-plus building focusing on increased user comfort. Part of this analysis is the main building and its extension. Figure 3-4 shows the different views of the building.

**Figure 3-4: Views of the school building. Starting in the upper left corner and rotating clockwise north, west, east, and south view.**

The  building has the following general characteristics:

- The building has three floors above and two below ground, though the heated area is limited to the floors above ground
- The total building net floor space is 2761.14 m²
- The building is used for primary and secondary education. There are no further usages in the building
- The building has three different stairwells (east, middle, and west)
- Interior walls are either dry walls, brick, or concrete walls, depending on their load-carrying ability
- Exterior walls are concrete or brick walls with varying exterior insulation material.
- The roof is a north light roof where the south part is equipped with PV modules

Figure 3-5 shows the floor plan of the 1st floor and highlights the different usages.

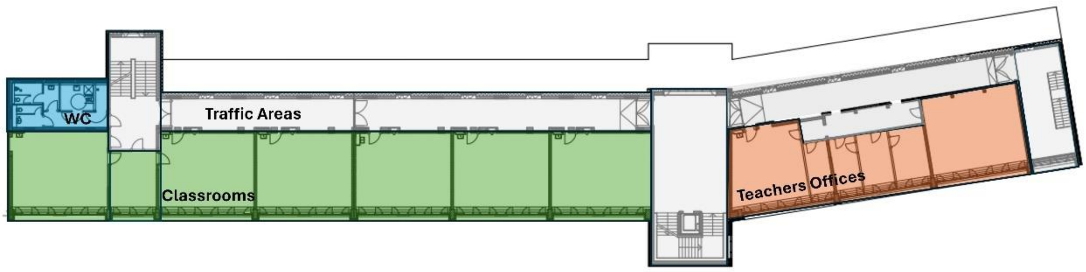



**Figure 3-5: Room usage types in the Uhland school building on the 1st floor**

For this analysis, three areas of modernisation and the resulting design decisions are important. Firstly, there are improvements to the hull; secondly, there is an entire revamp of the HVAC; and thirdly, there is the incorporation of onsite energy production, namely PV and geothermal energy.

### 3.2.1.1 Improvements to the hull

For the hull, the main focus was to reduce the thermal transmittance. Different insulation materials were used for different sections of the building. The three main materials are Expanded polystyrene foam (EPS), vacuum insulation panels, and mineral wool. All windows were exchanged and now have triple glazing. With these changes, the thermal transmittance could be reduced by 80%. Table 7 gives an overview of the changed U-Values of the building.

**Table 7: Overview of the improved U-values after the refurbishment and the measures taken to reach these values. (Wenger, 2018)**

| Component | U value ($W/m^2K$) before | U value ($W/m^2K$) after | Measure |
|---|---|---|---|
| Exterior wall, gable side | 1.70 | 0.17 | Additional 9 cm vacuum sandwich element |
| Exterior wall | 1.70 | 0.10 | Additional 30 cm thermal insulation |
| Exterior wall, ground floor, south | 1.70 | 0.15 | Additional 20 cm mineral wool insulation |
| Parapet, upper floor, south | 3.00 | 0.15 | Additional 20 cm mineral wool insulation |
| Window | 2.70 | 0.80 | Triple-paned diamond glass, high thermal insulating frames |
| Roof | 1.60 | 0.10/0.15 | Additional 30 cm EPS insulation / 9 cm vacuum insulation + EPS insulation |
| Floor/ceiling against ambient air | 2.50 | 0.25 | Additional 12 cm mineral wool insulation |
| Ceiling of the unheated cellar | 1.80 | 0.20 | Additional 14 cm mineral wool insulation |
| Floor against substrate | 3.10 | 0.47 | Additional 3 cm vacuum insulation |

### 3.2.1.2 Improved HVAC System

In general, the overhaul of the HVAC system now embodies a heightened level of technological sophistication. The building is divided into multiple zones adjusted to settings based on several parameters: room occupancy, building operational hours, weather conditions, and seasonal variations. Note that in this section, only the primary components are discussed.

The heating system was changed from coal-fired boilers with radiators to geothermal heat pumps. The heat is then distributed through capillary tube surfaces in the ceilings and parapet areas. This enabled a lower flow temperature of 37°C in the system. Furthermore, the regularly occupied spaces like classrooms and office spaces for teachers are conditioned at 17°C during opening hours (7:30 – 17:17) and lowered to 15°C. Corridors, WC, and other ancillary areas are set to 15°C during opening hours and lowered to 12°C. The entire tubing was changed to ensure minimal losses during the heat transportation.

In winter months (1 October – 31 March), the ventilation system works based on the CO2 concentration in the classrooms to reduce heat losses through natural ventilation. The ventilation system must have a 90% heat recovery rate to ensure minimal losses.

In the summer, the ventilation system is turned off and only operates at night to support the building's night cooling.

The cooling system can be divided into passive night cooling and active cooling through the reversed use of the heat pumps. The passive system automatically opens the windows and special ventilation vents on the second floor to enable cross-ventilation (cf. Figure 3-6: Schematic depiction of the night cooling through cross-ventilation. Special air vents on the first floor open the classrooms to the corridor. However, the ventilation vents and windows are closed if rain and wind are detected during the night, or the outdoor air temperature is higher than the indoor temperature. Additionally, the windows are closed if the room temperature falls below 18 °C.

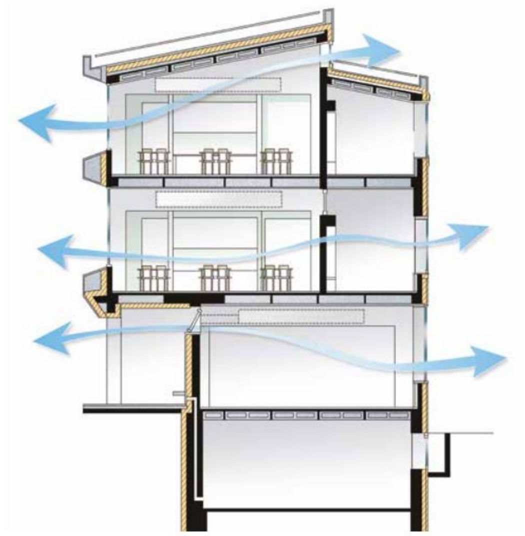


**Figure 3-6: Schematic depiction of the night cooling through cross-ventilation. Special air vents on the first floor open the classrooms to the corridor. (Wenger, 2018)**

The active cooling system utilises the ground probe field of the geothermal system by transferring excess heat from the classrooms to the geothermal field. This option is only available if the classroom heat exceeds 26 °C and is deactivated if it falls below 24 °C or to recharge the probe field with heat if a certain temperature is reached.

The lighting system is controlled by presence detectors as well as daylight sensors. An energy-efficient lighting concept was created with LEDs, low-light-density fixtures, and external sun-shading devices.

### 3.2.1.3 Onsite Energy Production

The PV system is located on the southern portion of the roof and the south side of the façade below the windows. 595 m² of PV area is located on the roof and 77m² on the façade. The used modules are BOSCH c-si m60 monocrystalline solar cells. This resulted in a capacity of roughly 100 kWp. Excess electricity is fed into the electricity grid. However, it must be mentioned that the provided data differed between the information brochure and the received plans. The data from the plan documents were used for the calculations and simulations.

The geothermal probe field consists of 52 probes, mostly situated north of the main building due to space constraints. Additional probes were sporadically placed on the south, east, and west sides. They are spaced at 8.5-meter intervals and drilled to approximately 90 meters deep, reaching the Haßmersheim stratum, a part of the upper shell limestone stratum. Further drilling was not feasible beyond this depth. In combination with the four heat pumps, a heating capacity of 128 kW is available.

### 3.2.2 Energy Standards and Design Choices of the Variants

The variants followed the design parameters for the energy demand in Chapter 2.1 and the hypothesis stated in Chapter 1.2. One major design decision of the case study was to reduce the energy demand by increasing the amount of insulation material. Therefore, four variants with less insulation material will be examined (variants 1-4). Additionally, the onsite energy production produces more energy than the building needs. Three variants with different percentages of on-site energy production (variants 2-4) examine whether this decision was right. To assess whether sustainable building materials could reduce the LCE of the building, two variants with renewable building materials are examined (variants 5-6). The chosen sustainable materials reflect an established insulation material, wood fibre insulation, and a more ambitious insulation material, straw. Table 8 lists all corresponding design decisions applied in the variant study.

**Table 8: Overview of the design variants and the corresponding energy standards.**

| Variant | Design Decision | Aimed Energy Standard |
|---|---|---|
| Base Case Uhland School | --- | --- |
| Variant 1: KfW 40 | Reduce insulation compared to the base case to reach the chosen Energy Standard with no onsite energy production. | KfW 40 – 60% less energy demand than the Reference Building; transmission heat loss 55% than the reference building |
| Variant 2: Passive Heating 65% | Reduce insulation compared to the base case to reach the Heating demand of a passive building; on-site energy demand covers 65% of the energy demand. | Passive House Heating demand |
| Variant 3: Passive Heating 100% | Reduce insulation compared to the base case to reach the Heating demand of a passive building; on-site energy demand covers 100% of the energy demand. | Passive House heating demand & zero energy building |
| Variant 4: Passive Heating & Energy Plus | Reduce insulation compared to the base case to reach the heating demand of a passive building; use on-site energy as the base case. | Passive House heating demand and plus energy building |
| Variant 5: Passive Sustainable Materials | Use the same amount of insulation material but a more sustainable one. | Energy Plus |

| | | |
|---|---|---|
| Variant 6: Passive Sustainable Materials 2 | Use the same amount of insulation material but a more sustainable one. | Energy Plus |

Though the revamp of the HVAC was also a major design decision, it was not changed, as different variants could not be properly depicted in the energy simulation and/or the LCA. In Honeybee (HB), the energy simulation program, different HVACs can be chosen from a list of pre-programmed components that can be adjusted with certain inputs like the system temperature or the heat recovery value. However, if certain parameters are outside these available inputs, the practitioner must program a new component, such as heating sails. This was outside of the scope of this master’s thesis. Furthermore, the number of available EPDs for technical building equipment in the Ökobaudat was limited, so a depiction of a varied HVAC system was further restricted.

The varied amount of on-site energy production was chosen based on the energy standard in the case of variants 2-4. For variant 2, the amount was based on the GEG that renewable sources should produce at least 65% of the energy in a new building (GEG, 2020/10/16/2023). For all other variants, the amount of onsite energy production stayed the same as in the base case.

## 3.3 Framework conditions of the ecological analysis – LCA

An LCA is conducted to assess the GWP of the different building variants, which follow the DIN EN 14040, DIN EN 14044, DIN EN 15643, and DIN EN 15978. As described in chapter 2.2.1, an LCA consists of a goal and scope definition, LCI, LCIA, and interpretation

This study aims to determine the GWP of the building structure components, technical building components, and the corresponding energy demand of different energy-intensive school building refurbishment design choices. The entire life cycle of the modernisation of the building is examined, from production and use to disposal. Stage D (reuse, recovery, and recycling) is assessed separately. The functional unit is m² netto floor space after DIN 277-1 of the school building with the same technical and functional requirements over a study period of 50 years. The system boundaries of the analysis are described in Chapter 3.3.1 for the LCA and Chapter 3.4 for the energy simulation.

For the LCI, all material quantities and types of the building components for the construction, including the respective maintenance cycles, are recorded in a building component catalogue. The amounts of energy required to operate the building are also recorded. The LCI is part of Appendix A. The method and input parameters of the energy simulation are presented in Chapters 3.4 and 4.2.

These determined energy and material values from the LCI are put into eLCA (version v.0.9.7) and linked to the ecological data of the ÖKOBAUDAT databank (OBD_2023_I_A2). Finally, by connecting the life cycle inventory of the buildings and the LCA data, the potential environmental impacts for the indicator GWP can be shown across all life cycle phases.

### 3.3.1 Chosen System Boundaries

The overall system boundaries are the boundaries of the building, meaning that outdoor installations like trees, parking spaces, or access areas are not part of the analysis. However, all components enclosed by the building envelope are. Figure 2-3 visualises the spatial system boundaries in red of the building.

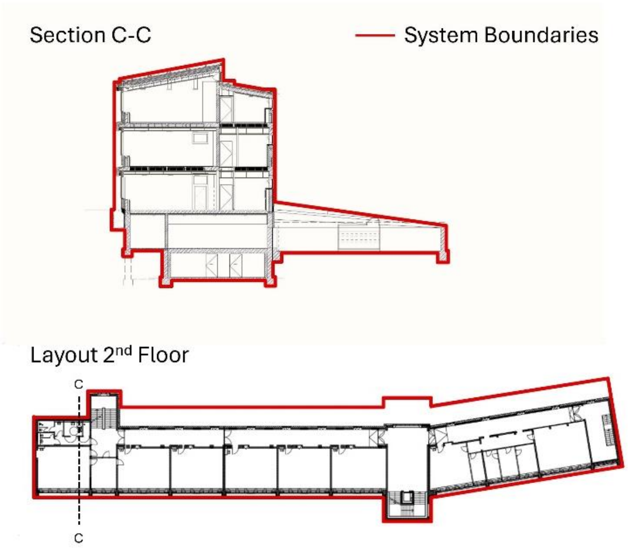



**Figure 3-7: Spatial system boundaries of the building are highlighted in red.**

The considered modules of an LCA follow the included values in the available EPDs. Therefore, the following modules of an LCA are part of the ecological evaluation of the building. The product stages A1-A3 (Raw material supply, transportation, manufacturing) are part of each EPD used for the LCA and are, therefore, part of this analysis. Modules “A4 Transportation to the construction site” and “A5 Construction installation process” are not part of the analysis. This follows the principles of the DGNB (see 2.2.2.2) and corresponds to the usage of generic data sets in eLCA where no data for modules A4 and A5 are available in most cases. Module “B1 Use” will also not be part of this analysis, as no data regarding the release of substances from the façade, roof, flooring, and other surfaces during the usage of the building is available. Modules B2 – B4 (Maintenance, Repair, Replacement) are considered by examining the maintenance cycles stored in eLCA; however, they are summarised under the term maintenance in the program eLCA. Module B5-Refurbishment is outside the system boundaries as future changes like room layouts, building usage types, or envelope changes are unknown and unlikely. Modul “B6 Operational energy use” will be considered by calculating the energy demand of the building. The system boundaries for the energy simulations will be explained in Chapter 3.4. Module “B7 – Operational Water use” is not part of the analysis as no relevant emissions arise from this module.

The energy demand for heating the service hot water is balanced in the energy simulation. For similar reasons as to why the construction process stages A4-A5 are not part of this analysis, the deconstruction processes "C1 Deconstruction/demolition" and "C2 – transportation" will not be considered. However, modules "C3 Waste Processing" and "C4 Disposal" will.

Different sub-cost groups could not be considered because of the spatial boundaries and the data available for the chosen LCA modules. Table 9 lists whether or not a cost group is part of the analysis.

**Table 9: List of included sub-cost groups in the LCA.**

| | | |
|---|---|---|
| **Included Materials (CG 300)** | | |
| 310 | Excavation pit | not included |
| 320 | Foundation | included |
| 330 | Exterior Walls | included |
| 340 | Interior Walls | included |
| 350 | Ceilings | included |
| 360 | Roofs | included |
| 390 | Other Measures | not included |
| **Included Technical Building Equipment (CG 400)** | | |
| 410 | Sewage, Water, and Gas installations | included |
| 420 | Heat supply systems | included |
| 430 | Ventilation systems | included |
| 440 | Power installations | included |
| 450 | Telecommunications and information systems | included |
| 460 | Conveyor systems | included |
| 480 | Building Automation | not included |
| 490 | Other Measures | not included |

Cost group 310 was excluded as the excavation pit is the same for all variants and outside the spatial system boundary. Furthermore, reliable data regarding the machines used for the excavation process and the excavated amount of material was unavailable. Lastly, as the building was a refurbishment of an old building, only a limited volume was excavated to renew and reinforce foundations and perimeter insulation, reducing the influence of cost group 310 on the results. Even though major parts of the technical building equipment are automated, the CG 480 could not be represented. On the one hand, the amount of installed sensors, for example, for daylight control or present detection, could not be accurately identified. Furthermore, the corresponding datasets are unavailable on eLCA and using product-specific EPD data without the exact product configurations would misrepresent the actual building automation equipment. Lastly, Weißenberger (2016) showed that CG 480 only has a marginal impact on the overall ecological performance of a building and can therefore be neglected.

For the components of the existing building, neither manufacturing, maintenance, nor end-of-life are considered. This follows the system boundaries of the DGNB for the certification of a refurbished building (DGNB, 2021). Nonetheless, the amount of concrete and bricks in the old building is documented in the component catalogue but not integrated into the LCA.

For the temporal component of the system boundaries, 50 years was assumed as this is the most common time frame used in German certification programs and other LCAs (cf. 2.2.2.2).

### 3.3.2 Data Foundation for the LCA

The data basis for the LCA calculation consists of a component catalogue for the cost groups 300 and 400. This inventory data, meaning mass and material determination, is primarily based on planning documents and the information provided by construction contractors (such as measurements, order forms, and post-calculations), as well as engineering calculations, including assumptions. In Germany, the building process is divided into different service phases called “Leistungsphasen”. The available plan documents are part of “Leistungsphase 5 – Ausrühurungsphase” (implementation planning phase). “Leistungsphase 5” is a crucial stage in the architectural and engineering design where detailed plans and specifications are developed. Determining the exact materials, products, and systems to be used in the construction process and creating comprehensive construction drawings and detailed plans that provide precise instructions for construction and form a good basis for an LCA. A detailed breakdown of the inventory data can be found in Appendix A; sections are shown in Chapter 4.1.

The LCA was then conducted in eLCA v.0.7.9 in conjunction with the database ÖKOBAUDAT OBD_2023_I_A2. The database provides generic, average, and product-specific EPDs. If possible, generic datasets are chosen over average and product-specific. As there was no generic or valid EPD for a vacuum insulation material in eLCA available, a product-specific EPD from the company “Porextherm Dämmstoffe GmbH” with the declaration number EPD-POR-20200138-IBC1-DE was chosen (cf. Appendix B). The EPD follows EN 15804+A1. Originally, it was intended to average the value from different product-specific EPDs, but no other valid EPD could be found. The data from the EPD was then added to the results from eLCA in an Excel sheet. The suggested service life from the BBSR is used for the vacuum panels' service life, which equals 30 years (BBSR, 2017). This means that for the chosen reference study of 50 years, the vacuum panels have to be exchanged once. A similar process was followed for the straw insulation of the sustainable building variant. No dataset was available for the product in the ÖKOBAUDAT database. Therefore, the EPD for “Straw as insulation material” with the declaration number EPD-NIBE-20210706-2040 was implemented. The EPD follows EN15804:2019+A2 (cf. Appendix C).

Furthermore, quantifying the length and thickness of electronic cables and pipes was impossible. Additionally, only limited data sets in the ÖKOBAUDAT database and from the company for technical building components were available, so the base amount from the QNG was used. It includes the listed items in Table 10 sorted after their respective cost groups. However, the base amount does not distinguish between the LCA stages and only gives a value for the stages A1-A3, B4 and C3-4. The chosen value for the building is 1.2 kg $CO_2$ equ./m²*a. (QNG, 2023)

**Table 10: Included components in the base mount of the QNG sorted after their respective cost groups (QNG, 2023).**

| Cost Group | Components Included in the Basic Amount |
|---|---|
| 410 | Riser and fall pipes, connection pipes for apartments, and all sanitary objects |
| 420 | Pipelines, distributors for room heating devices, room heating devices |
| 430 | Pipelines, distributors, connection pipes for ventilation |
| 440 | Low voltage main distributors, cables, lines, sub-distributors |
| 450 | Empty conduits, cables, lines, personal call systems, light call and bell systems, intercom and door opener systems |

The QNG is a German state certification aimed at promoting sustainable construction. It is awarded by the Federal Ministry of Housing, Urban Development, and Building to buildings that meet stringent environmental, socio-cultural, and economic criteria. The QNG seal is increasingly recognised and adopted within the construction industry. It aligns with other certification systems like the DGNB. (BWSB, 2024)

## 3.4 Framework Conditions for the Energy Simulation

This paper's simulations are conducted with a dynamic white box program called HB, as the input parameters of the case study are well known, and the advantage of clear relations between design variations only becomes present in a white box model. HB is a plug-in for the visual programming language Grasshopper, which is used with Rhino, a 3D modelling software. HB connects the geometry inputs with energy simulation inputs like climate data or HVAC system configurations and uses Energy Plus and Open Studio engines to calculate the energy demand. As Energy Plus is one of the most established simulation engines (cf. chapter 2.3) and HB is open-source, HB was chosen as the simulation program for this thesis.

In Grasshopper and HB, data can be put into the software by using the graphical user interface, which relies on a library of pre-programmed building blocks called components; alternatively, code-based instructions in Python can be used to program specific solutions. Figure 3-8 shows a section from the Grasshopper canvas highlighting HB's graphical user interface in which building material is configured.

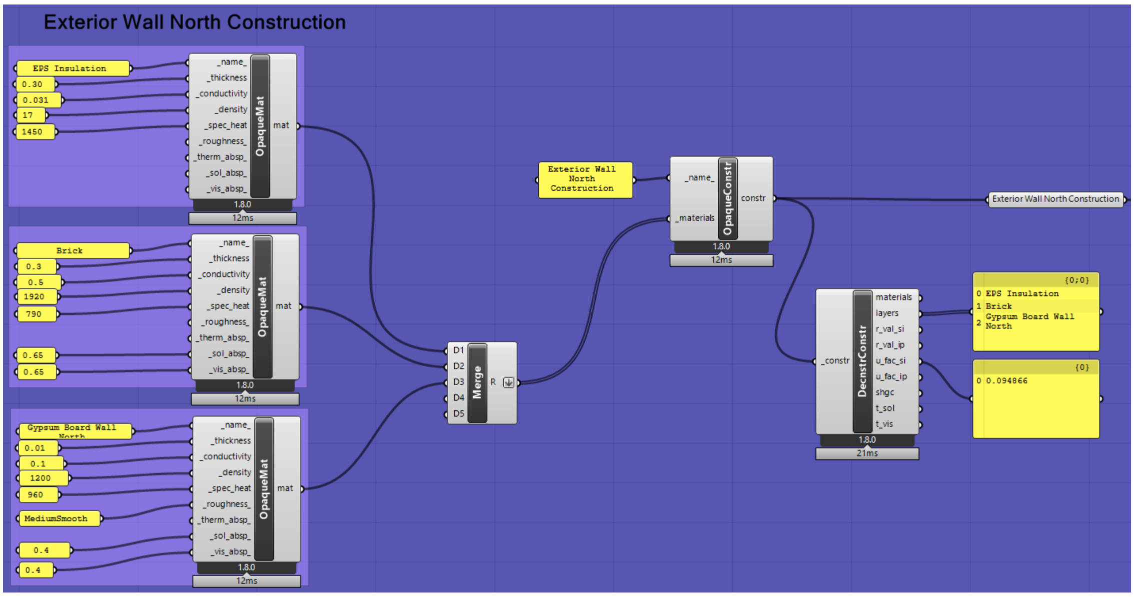



**Figure 3-8: Example of the graphical user interface of Grasshopper and HB. (own picture)**

Note that the information flow works from left to right, and circular patterns are impossible. Yellow boxes are panels that can be used to input data like the U-value of a certain material layer or to visualise outputs from the components like the location of the used weather file. Pre-programmed components (grey) have necessary inputs that are marked at the beginning with an "_" and optional inputs that are marked with an "_" at the beginning and end. For most components, pre-set base values are set and can be edited through different inputs or Python. However, this requires a higher level of sophistication in the programming language and the technical workings of building equipment.

Table 11 lists the versions of the program used for this paper, which, at the time of the publication of this thesis, were the latest accessible versions to the author.

**Table 11: Overview of the versions used in the energy simulation**

| Name | Version |
|---|---|
| Rhino 3D | 8.6.24101.5001, 2024-04-10 |
| Grasshopper | 10 April 2024 05:00 Build 1.0.0008 |
| Honeybee | 1.8.12 |
| Energy Plus | 23.1.0-87ed9199d4 |
| Open Studio | 3.6.1+bb9481519e |

In general, the method for a simulation with HB follows these steps:

1. Generation of a geometry and zoning either in Rhino or through parameters defined in Grasshopper
2. Input of technical and climate data information with HB
3. Run Simulation based on the "energy plus" and "open studio" engines.
4. Evaluate the results and, if necessary, adjust inputs

Figure 3-9 shows the simulation workflow and at which points the different inputs, plug-ins, and engines intersect.

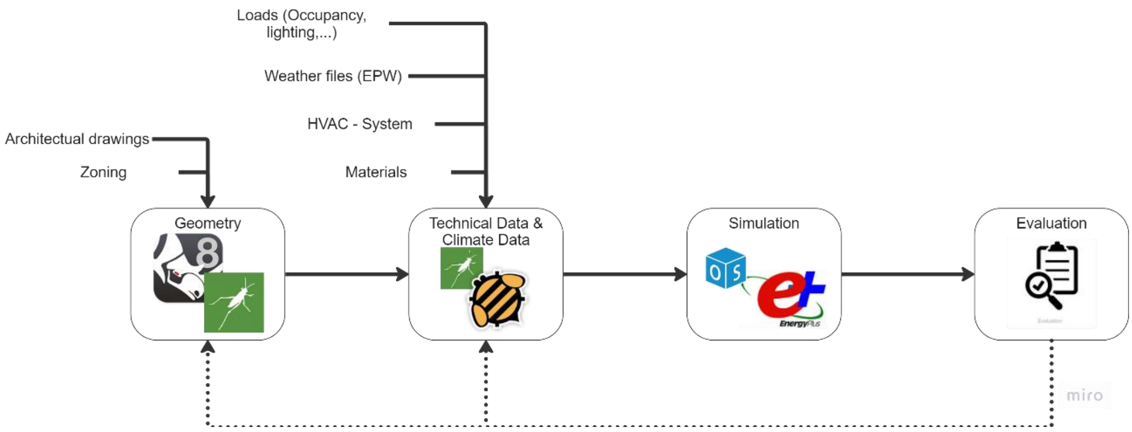



**Figure 3-9: Work Flow of the Simulation Program HB**

The following explains the workflow used in Rhino and HB in more detail. In the first stage, the Geometry of the building is derived from the architectural plans and simplified. This means that entire rooms are depicted as solids, and complex façade structures are simplified to reduce the computational time of the simulation. Common usage types of rooms can then be combined into similar zones. Zones are parts of the building volume and are thus the fundamental building blocks of a Building Energy Model (BEM). The number and distribution of zones can be chosen according to the requirements of the BEM. A finer division into zones generates more accurate results but leads to more calculations and longer computation times.

In the second stage, the geometry is imported into Grasshopper and HB, and technical and climate data are assigned to the different zones with the help of construction sets, zone programs, weather files, and HVAC system components. A construction set comprises different material components defined by a list of material layers, orientation, and relations toward the outside. Materials are defined by thickness, thermal conductivity, density, and specific heat capacity. Subsequently, materials are combined into material components, following a specific order (cf. Figure 3-8). These components are then assigned to the walls or floors of the zone depending on their orientation and relationship to other walls or the outside, e.g., vertical components (walls), lower horizontal components (e.g., floor slabs, ceilings), and upper horizontal components (e.g., roof, ceiling), as well as three boundary conditions: component against outdoor air, component against the ground, or adiabatic component. Typically, six faces define a zone: exterior walls, roof/ceiling, windows, interior walls, and floor. Each face is assigned the corresponding geometry (2D surface) of the zone in the building model. Thus, each zone is formed. The composition of all zones constitutes the HB model (building), based on which the BEM is executed.

In addition to the construction sets, boundary conditions for each zone are set via HB programs. Boundary conditions include, for example, the type of heat generation, internal loads (people, lighting, devices, and hot water), building tightness, ventilation, etc. Boundary conditions can be set as static (constant over time) or dynamic (changing over time). Generally, dynamic boundary conditions are chosen based on schedules, as these reflect the actual use of a building. For example, the occupancy of a building can be set dynamically. During the day, an office may have 100% occupancy, while at night, it is assumed to be unoccupied.

In the third stage, all zones are combined in the simulation component. The simulation is run with the EnergyPlus engine. However, no knowledge of EnergyPlus is necessary for running a BEM in HB; the programs run in the background, and all settings are made before the simulation starts within the HB user interface in Grasshopper.

The overall system boundaries for the building energy simulation (BES) are shown in Figure 3-10. They represent the demands for heating, hot water supply, support energy, ventilation, lighting, appliances, and on-site energy production. Compared to a GEG certification, the electricity demand for appliances is part of the analysis as it is important to quantify it when analysing energy buildings. A newspaper article highlighted the importance of quantifying the appliance's energy demand for the case study as the originally planned PV area had to be increased as the new electronic whiteboards would otherwise use more energy than provided by the PV system so that the energy standard of a plus energy school could still be met (Schwarz, 2014).

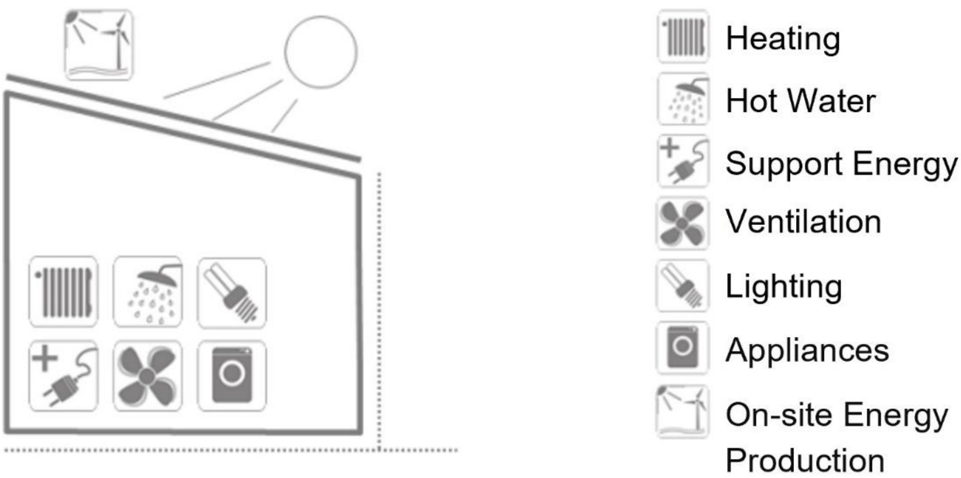



**Figure 3-10:System boundaries for the BES. (translated from Mahler et al., 2019)**

Furthermore, the internal gains from the occupancy, solar radiation, or resulting from energy demands, e.g., waste heat from the lights, are also part of the simulation. Thus, the system boundaries of the BES are at the building boundary. This means that influences from other buildings and landscapes, such as context shading from other buildings or vegetation and the waste heat from adjacent buildings, are not considered.

# 4 Application of the Methodology

Following the definition of the framework conditions, Chapter 4 explains the application of the LCA and the BES. Furthermore, the variants stemming from the design choices and energy standards are defined, and an overview of the scenarios that expand the system boundaries is shown.

## 4.1 LCA

The calculations for the building components catalogue and the linked datasets in eLCA follow roughly the same approach for each component of the same type. Therefore, only three examples are explained in detail. The chosen items, Standard façade – south (alternating insulation), load-bearing interior wall, and Windows South Classroom 101;103-107 well represent the process. Furthermore, based on these three examples, the linked datasets in eLCA are given. The remaining components can be found in Appendix A.

In general, the process of calculating the amount of material followed these steps:

1. Identifying the dimensions from the plan documents (floor plans, if available, sections and details, otherwise using logical assumptions)
2. Identify the component layer setup from the building physics report and plan documents
3. Document findings in the building components catalogue
4. Incorporate material surface area and width into eLCA and link it with the corresponding data sets.
5. Combine results of eLCA with additional data sets that are outside of the ÖKOBAUDAT in Excel

In general, the component catalogue was divided into each floor. Furthermore, windows and doors are listed in a different section, as are the walls of the stairwells. The reasons for this are that the height of the stairwells differed from the height of the floors, and a clear allocation to a single floor was impossible. Furthermore, the attics and pent ridges of the roofs are also listed separately.

The different layers and corresponding dimensions of the standard façade–south (alternating insulation) can be seen in Table 12. Furthermore, the names of the source documents used for measuring the dimensions of the components are listed, as well as the corresponding eLCA datasets.

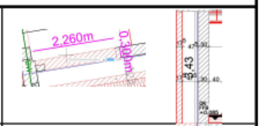
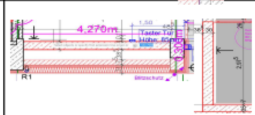
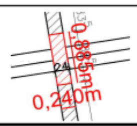
**Table 12: Section from the building components catalogue: Standard façade – south (alternating insulation)**

| Cost Group - CG | Sub Cost Group | Name of Cost Group | Name in the Buildings Physic Report | Location in the Building | Name of the Building Component Layer | Layer thickness [m] | Amount [m2] | Sources - Documents Name | Comments | Linked eLCA Dataset |
|---|---|---|---|---|---|---|---|---|---|---|
| 330 | | Exterior Wall | AW Süd OG Beton MW mit PV | Exterior Wall South | Standard façade - south (alternating insulation) | | | IBP_Sanierung Uhlandschule; 1A_21104OG1-1_0(Wandaufbauten); Views: 1A_21022AS_I; Sections AA-FF; Window Details | Parts of the façade have different insulation materials | |
| 440 | 442 | Internal power supply systems | | Exterior Wall South | PV-Modules | | 42,7 | | | Photovoltaic system 1000 kWh/m²*a (no electricity credits) |
| 330 | 335 | External wall cladding outside | | Exterior Wall South | Synthic resin plaster | 0,015 | 151,9 | | | Synthtic resin plaster; Synthetic resin |
| 330 | 335 | External wall cladding outside | | Exterior Wall South | Isover Ultimate | 0,2 | 74,0 | | | Mineral wool (facade insulation); 46 kg/m3 |
| 330 | 335 | External wall cladding outside | | Exterior Wall South | Stone Wool | 0,2 | 77,9 | | | Mineral wool (facade insulation); 46 kg/m3 |
| 330 | 331 | Load-bearing exterior walls | | Exterior Wall South | Concrete | 0,3 | 151,9 | | | Ready-mix concrete C25/30; Reinforcement steel wire |
| 330 | 336 | Internal external wall cladding | | Exterior Wall South | Plaster | 0,01 | 151,9 | | | Gypsum interior plaster; 1000 kg/m3 |

The component "standard façade – south (alternating insulation) included two different insulation materials: stone wool insulation and glass wool insulation. This was probably necessary as using PV modules on the façade resulted in different requirements for fire safety. However, in eLCA, only generic datasets for mineral wool for façades consisting of 50% stone wool and 50% glass wool were available. Therefore, the same eLCA dataset was chosen. Most of the load-bearing walls (both interior and exterior) were unchanged from the original design. Therefore, these were not included in the LCA, and the amounts were marked in black in the component catalogues.

The amount of new load-bearing structure was calculated in a separate Excel sheet. Table 13 shows a section from the Excel sheet calculating the volumes of new brick and concrete walls, foundations and floor slabs. In eLCA, the data set "Brick (unfilled)" was chosen for a brick wall, and for a concrete wall, the dataset "read-mix concrete C25/30" in combination with "reinforcement steel wire" was chosen. The degree of reinforcement was set at 2%. The strength of the concrete for concrete walls, foundation and floor slabs is based on the static calculations conducted by "Monke Höss Bauingenieure" for the school building.

**Table 13: Section from the calculations to determine the new concrete and brick wall amount.**

| Location | Material | Length | Width | Hight | Area | Volume | Comment | Screenshot |
|---|---|---|---|---|---|---|---|---|
| Interior Wall | | | | | | | | |
| Interior Wall; Stairwell East, Orientation South | Brick Wall | 2,26 | 0,3 | 3,43 | 7,75 | 2,33 | Assumption: Filling of old entrance door |  |
| Interior Wall; Stairwell middle, orientation South | Concrete | 4,27 | 0,3 | 3,045 | 13,00 | 3,90 | Assumption: Filling of old entrance door |  |
| Interior Wall; Building extension, Section K-L | Brick Wall | 0,885 | 0,24 | 3,43 | 3,04 | 0,73 | Repair of load-bearing inner wall |  |

The calculation sheet has a description of the location of the new section in the plan documents, the type of material used, the dimensions, a comment on why the new section was necessary and a screenshot of the measurements taken. Furthermore, if assumptions were necessary, the corresponding cell was marked with a comment. For example, for both brick walls in Table 13, no section was available to determine the height of the new brick wall. Therefore, it was estimated that the entire section from the floor to the ceiling had to be renewed. This represents a conservative estimation.

Part of the component catalogue is a list of all windows, a section of which is provided in Table 14. The component catalogue includes the name of detailed plan documents, a description of the window's location, a component name, the amount of this window design in the building, the dimensions, and the corresponding name of the component in eLCA.

**Table 14: Section from the component catalogue: Windows South Classroom 101;103-107**

| Cost Group | Sub Cost Group | Source Document Name | Location | Component Name | Amount | Width | Area [m²] | Name of the components in eLCA |
|---|---|---|---|---|---|---|---|---|
| 340 | 334 | 109 2.1.36 Hauptgebäude 1.OG | Windows South Classroom 101;103-107 | Window with PV | 6 | 8,995 | 18,53 | 1 Fenster OG 1 Süd Fenster Klasse101;103-107 Teil Nicht öffenbar<br>2 Fenster OG 1 Süd Fenster Klasse101;103-107 Teil öffenbar |

The windows were modelled in eLCA with the help of the window designer. The window frame's width, frame materials, glazing, fittings, handles, sun shade, and interior and exterior window sill can be defined. However, with the help of the window designer, no alternating window panels with a blind frame and a sash or only a blind frame can be modelled. Therefore, the windows were split into different components. In the case of the “Windows South Classroom 101;103-107”, two eLCA components were necessary to accurately depict the actual window. Table 15 lists the different input parameters in eLCA for both components.

**Table 15: Different inputs for the two components of the "Windows South Classroom 101;103-107"**

| | | Component 1 Operable | Component 2 not Operable |
|---|---|---|---|
| Dimensions | Width [m] | 4,44 | 4,2 |
| | hight [m] | 2,06 | 2,06 |
| | Connection joint [mm] | 20 | 20 |
| | Blind Frame [cm] | 4,9 | 2,4 |
| | Sash [cm] | 6,2 | --- |
| | Windowsill interior [cm] | 2x40 | 2x40 |
| | Windowsill exterior [cm] | --- | --- |
| Devision | Post | 5 | 4 |
| | Bolt | 0 | 0 |
| Datasets | Blind Frame | Aluminium wing sash profile, powder coated | |
| | Sash | Aluminium wing sash profile, powder coated | |
| | Glazing | Insulated glazing, triple pane | |
| | Connection Joint | Elastomer joint tape, polyurethane | |
| | Fittings | Window fitting for tilt and turn window | --- |
| | Handles | Window handle | --- |
| | Sun Shade | Sun protection (metal blinds) | |
| | Windowsill interior | Artificial stone slab (epoxy-resin bound) | |
| | Windowsill exterior | --- | --- |

The eLCA datasets were chosen according to the details provided by the plan documents. If no information was available, for example, the material used for the connection joints, assumptions were made.

# 4.2 Simulation

The following describes the parameters applied to the BES and on-site energy production simulation. The simulation was divided into the on-site energy production and the BES. This was done as the on-site energy production used a better representation of sun rays to more effectively depict the solar radiation necessary for a PV simulation. This results in a higher simulation time and would have otherwise made the variant studies of the building hull extremely time-consuming.

## 4.2.1 Building Energy Simulation

**Zoning –** The building is divided into 26 Zones with four different usage types.

- Classrooms (marked in green)
- Utility Rooms
- WC (marked in blue)
- Corridors (marked in grey)

Figure 4-1 depicts the different zones for the 1st floor. Part of Appendix D is the zoning plan for the remaining floors.

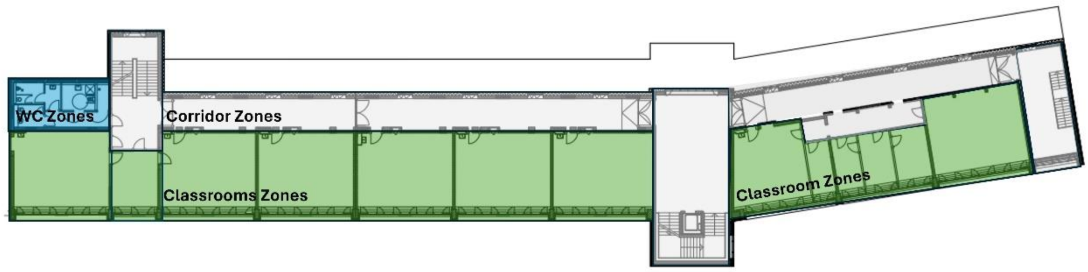



**Figure 4-1: Zone types for the different areas of the building.**

Different rooms can be combined into the same zone if they have the same parameters set for the conditioning of the rooms, construction sets (U-values), programs (internal loads like occupancy and lighting levels), schedules (dynamic temperature values for a day), HVAC Systems (ventilated or not ventilated). For example, even though the usage differs for the classrooms and the teacher's office spaces, the remaining parameters are the same, so they get the same zoning parameters as a classroom in the BES.

**Construction sets** – each zone has its own construction set representing the component layers in the building. Table 16 lists the different construction sets for each zone type. The construction sets represent the average U-values for the external envelope components derived from the building physics report.

**Table 16: List of different construction sets for each zone with the insulation material and the corresponding U-Value for the other envelope components.**

| Zone | Envelope Component Typ | Insulation Material [mm] | Corresponding U-value [W/Km²] |
|---|---|---|---|
| Classroom | Exterior wall<br>Interior wall<br>Roof<br>Ceiling<br>Exposed floor<br>Window | Mineral wool<br>n.a.<br>EPS 300<br>n.a.<br>Mineral wool 120<br>Tripple pane | 0.14<br>0.31<br>0.096<br>0.70<br>0.24<br>0.80 |
| Corridors | Exterior wall<br>Interior wall<br>Roof<br>Ceiling<br>Exposed floor<br>Window | EPS 300<br>n.a.<br>EPS 300<br>n.a.<br>Mineral wool 120<br>Tripple pane | 0.095<br>0.31<br>0.096<br>0.70<br>0.24<br>0.80 |
| Utility Rooms | Exterior wall<br>Interior wall<br>Roof<br>Ceiling<br>Exposed floor<br>Window | Mineral wool 200<br>n.a.<br>EPS 300<br>n.a.<br>Mineral wool 120<br>Tripple pane | 0.15<br>0.31<br>0.096<br>0.70<br>0.24<br>0.80 |
| WC | Exterior wall<br>Interior wall<br>Roof<br>Ceiling<br>Exposed floor<br>Window | VIP 90<br>n.a.<br>EPS 300<br>n.a.<br>Mineral wool 120<br>Tripple pane | 0.16<br>0.31<br>0.096<br>0.70<br>0.24<br>0.80 |

Further material information, like density or specific heat capacity, was taken from EPDs of the product type. This also applied to products used in the variants.

Note that only a single component type can be defined for each zone. This means that the changing façade insulation materials can only be limitedly depicted for the simulation. For example, the classroom in the southwest has a different component layer compared to the actual building for the exterior wall to the west. However, this simplification is limited to a small surface area, and the differences in the U-value are small.

**Programs & schedules** – the different programs govern the internal gains like heat from occupancy or lighting levels. Furthermore, through schedules, dynamic occupancy or lighting use can be modelled. The internal loads and gains are based on the building physics report. The appliance load is the same for the entire zone as it is derived from an analysis of the school building and results to the 2.72 W/m². As the study does not indicate how the electricity demand varies in the different areas of the building, the average value was chosen for all zones. (Jacobsen et al., 2015) Table 17 lists the various parameters of each zone program and the schedules used. An exemplary overview of the different schedules for the classroom zone is given in Table 18. The remaining schedules are part of Appendix E.

**Table 17: List of the different program parameters for each zone.**

| Parameter | Zone Classroom | Zone Corridor | Zone Utility Rom | Zone WC |
|---|---|---|---|---|
| Occupancy | 0.337 people/m² | 0 people/m² | 0.377 people/m² | 0 people/m² |
| Schedule | Occu. Classroom | --- | Occu. Classroom | --- |
| Lighting | 5.72 W/m² | 4.08 W/m² | 5.72 W/m² | 5.95 W/m² |
| Schedule | Lighting Classroom | Lighting Corridor | Lighting Classroom | Lighting Classroom |
| Daylight control | Yes | Yes | Yes | Yes |
| Set Point | 300 lx | 100 lx | 300 lx | 200 lx |
| Service Hot Water | --- | --- | --- | 0.75 L/hm² |
| Schedule | | | | Service Hot Water WC |
| Infilatration | 0.000227 m³/sm² | 0.000227 m³/sm² | 0.000227 m³/sm² | 0.000227 m³/sm² |
| Schedule | --- | --- | --- | --- |
| Heating | Yes | Yes | Yes | Yes |
| Schedule | Classroom Heating | Corridor Heating | Classroom Heating | WC Heating |
| Cooling | Yes | No | Yes | No |
| Schedule | Classroom Cooling | --- | Classroom Cooling | --- |
| natural Ventilation | Yes | Yes | Yes | Yes |
| Schedule | always | always | always | always |
| T min - max inside | 22 -25 °C | 22 -25 °C | 22 -25 °C | 22 -25 °C |
| T min - max outside | 15-26 °C | 15-26 °C | 15-26 °C | 15-26 °C |
| % operable Area | 50% | 50% | 50% | 50% |
| mechanical Ventilation | Seasonal | No | Seasonal | Yes |
| Schedule | Classroom Ventilation | --- | Classroom Ventilation | WC Ventilation |
| Heat Recovery | 75% | --- | 75% | 75% |

**Table 18: List of different schedules of the zone Classrooms. A fractional schedule represents a certain % of the availability of the system. A temperature schedule represents the set point temperature of a system. W=Weekday, WE= Weekend, H=Holiday**

| Hours of the day | Occupancy classrooms Fractional | | | Lighting class-rooms fractional | | | Heating class-rooms temp. | | | Cooling class-rooms temp. | | | Ventilation class-rooms winter fractional | | | Ventilation class-rooms summer fractional | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W | WE | H | W | WE | H | W | WE | H | W | WE | H | W | WE | H | W | WE | H |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | 26 | | 0 | 0 | | | 0 | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 8 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 9 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 10 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 11 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 12 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 13 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 14 | 1 | 0 | 0 | 0.5 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 15 | 1 | 0 | 0 | 0.5 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 16 | 1 | 0 | 0 | 0.5 | 0 | 0 | 17 | 17 | 15 | | | | 1 | | | | | |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 1 | | | | | |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 1 | | | | | |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 1 | | | | | |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 1 | | | | | |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 1 | | | | | |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 1 | | | | | |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 1 | | | | | |

A weekday is defined as Monday-Friday, weekends are from Saturday to Sunday, and the holidays follow the school calendar of the federal state of Baden Württemberg. A list of the holidays used is shown in Appendix F. The following describes how the schedules are read with the stored zone programs. An example of a fractional schedule and a temperature schedule is provided. The fractional occupancy schedules mean that during weekdays from 8-17, the full occupancy value of 0.337 people/m² is assumed. During the remaining time, the zone will be unoccupied. The temperature schedule for the classroom zone governs the set point temperature for heating and cooling. For example, during occupancy on a weekday between 8-17, the classroom zone is conditioned at 19°C by the heating system. Outside the occupancy hours, the temperature drops to 17°C, and during longer unoccupied days like holidays, the temperature is lowered to 15°C.

**HVAC** – The HVAC is modelled with a preprogrammed component from HB called ideal air. It is used when the user aims to evaluate a building's performance without having to model an entire HVAC. This decision was made because of two reasons. Since HB is designed for American buildings, the exact modelling of conventional energy systems for the European market is complex and beyond this thesis. The second reason is that the subsequent LCA focused on the building envelope and on-site energy production as they had the biggest share in EC (cf. Chapter 5.1), and only limited datasets are available on eLCA for different HVAC, so a good representation of a changing HVAC is not possible.

**Weather files and simulation parameters –** The weather file “Stuttgart-Schnarrenberg BW DEU107390TMYx” is used for the simulation. The location of the weather station is less than a kilometre away from the project location and represents, therefore, perfectly the climatic conditions. The distance was measured with Google Maps. Further simulation parameters are listed in Table 19.

**Table 19: List of additional simulation parameters**

| Simulation Parameters | Set Values |
|---|---|
| Simulation Output | Zone Energy use, System Energy Use, Gains and Losses, Reportfrequenzy Monthly |
| Shadow Calculation | Minimal Shadowing, Method Polygon clipping, Frequency Periododicly, |
| Analysis Period | Hole Year |
| Holidays | 91 Valus, the List is in Appendix F |

## 4.2.2 PV-Simulation

The PV system simulation followed the same principles as the energy simulation except that the building was reduced to a single zone as the interior performance of the building does not matter, only the geometrical shape and the resulting shadows. Figure 4-2 shows the final geometrical shape of the building in grey, while the surfaces of the PV area are highlighted in green. The positions and sizes were taken from the architectural documents and the technical data sheets from the PV modules.

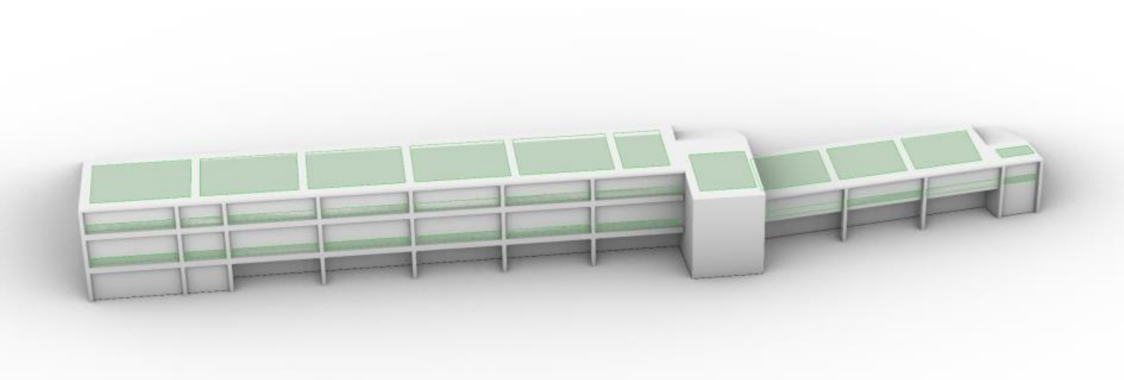


**Figure 4-2: Model used for the PV-Simulation of the Base Case. Areas in green highlight the PV Modules.**

After importing the geometries into Grasshopper and HB, the properties for the building and PV systems can be assigned. In this simulation, all pre-set construction sets and programs are used to generate the HB rooms, as further input is unnecessary for the onsite electricity generation. The material properties of the PV models can be applied to the surfaces using the “HB photovoltaic properties component”. It allows the following inputs:

- Rated efficiency in per cent of the PV module
- Active fraction in per cent: the proportion of the PV module area to the PV cells area
- The module type which corresponds to the rated efficiency
- Mounting Typ: Fixed open rack, fixed roof-mounted, one-axis, one-axis with backtracking, and two-axis
- Loss fraction in per cent: including soiling, snow, wiring losses, electrical connection losses, manufacturer defects/tolerances/mismatch in cell characteristics, losses from power grid availability, and losses due to age or light-induced degradation
- Ground coverage ratio for one-axis arrays

Table 20 shows the actual input for the simulation. The default inputs were used for the components „HB Room to solid“ and „HB Shade“as they do not influence the output of the simulated PV modules.

**Table 20: Overview of the inputs of the different components for the PV simulation**

| Component | Inputs | Value |
|---|---|---|
| Hb Room to Solid | Construction set | default |
| | Programm | default |
| | Conditioned | default |
| HB Shade | Construction Set | default |
| | Transmittance Schedule | always opaque |
| HB Photovoltaic Properties | Rated efficiency | 0.168954 |
| | Active fraction | 0.9 (default) |
| | module type | Standard |
| | Mounting Typ | Fixed Roof-Mounted |
| | Loss fraction | 0.14 (default) |
| | Ground coverage | not applicable |

The rated efficiency was calculated after the following formula (Engasser, 2023):

$$r\,[\%] = \frac{kW_p\ of\ the\ PV\ panel\ [kW]}{Area\ \ of\ the\ PV\ panel\ [m^2]} = \frac{0.28}{0.99*1.674} = 0.168954\,\% \qquad (3.1)$$

The data was taken from the data sheet of the used PV model “Bosch Solar Module c-Si M 60”. The data sheet is part of Appendix G. The default values were chosen for the input's active and loss fraction, as no detailed information about the system is available. Lastly, the zoning and material properties were combined in the HB Model component, one of the inputs for the HB Generation Loads simulation component. Table 21 shows the different inputs of the component, though mostly the default values were chosen as no additional information about the actual systems was available.

**Table 21: Overview of the different inputs for the HB Generation Loads.**

| Component | Inputs | Value |
|---|---|---|
| Hb Generation Loads | HB objects | Output of the HB Model Component |
| | Epw file | Stuttgart-Weissenburg BW DEU-107370-TMYx |
| | North | 0° |
| | Inverter efficiency | 0.96 (default) |
| | Direct current to alternating current | 1.1 |

The outputs of interest were the total alternating kWh and each photovoltaic object's direct current to better understand the impact of the roof PV and facade PV models. The entire Grasshopper canvas is part of Appendix H.

# 4.3 Variants

The energy simulation and the LCA had to be adjusted to achieve the energy standards with the varied design choices presented in Chapter 3.1.2. This included the thickness of the insulation, the chosen insulation material and the onsite energy demand. However, as mentioned earlier (cf. Chapter 3.2.2 & 3.4), the HVAC system, with the underlying programmes and loads, was not adjusted. Table 22 shows the adjusted materials, thicknesses and on-site energy production. The used materials in the variants are based on the base case's most commonly used insulation material, except for the variants where a more sustainable insulation material was used. The thickness of the insulation non-renewable materials was defined to fulfil the requirements of the energy standard. The thickness of the renewable materials is based on the thickness of the corresponding insulation material in the base case, as a thickness of more than 300mm seems unrealistic. Furthermore, it was kept the same in areas where the insulation material needed to fulfil a specific function that sustainable material could not, for example, for the fire protection strip or the insulation for the elevator. The onsite energy demand also followed the definitions of the energy demand. In the case of the plus energy building standard, the surface area of the base case was chosen as the standard only defines that more energy has to be produced over the year but not a precise amount.

**Table 22: Design decisions and corresponding energy demand of the variants.**

| Variant | Insulation material | Insulation thickness [mm] | Share of on-site energy production [%] | Surface area of PV-modules [m²] | Final energy demand [kWh/a] |
|---|---|---|---|---|---|
| Base Case Uhland School | Exterior Wall: EPS, VIP, Mineral Wool<br>Roof: EPS<br>Exposed Floor: VIP, Mineral Wool | 300, 90, 200<br>300<br>40, 120 | 140 | 672 | 70,000 |
| Variant 1: KfW 40 | Exterior Wall: EPS<br>Roof: EPS<br>Exposed Floor: XPS | n.a. | n.a. | n.a. | n.a. |
| Variant 2: Passive Heating 65% | Exterior Wall: EPS<br>Roof: EPS<br>Exposed Floor: Mineral Wool | 120<br>150<br>100 | 65 | 376 | 87,400 |
| Variant 3: Passive Heating 100% | Exterior Wall: EPS<br>Roof: EPS<br>Exposed Floor: Mineral wool | 120<br>150<br>100 | 100 | 585 | 87,400 |
| Variant 4: Passive Heating & Energy Plus | Exterior Wall: EPS<br>Roof: EPS<br>Exposed Floor: Mineral Wool | 120<br>150<br>100 | 110 | 672 | 87,400 |
| Variant 5: Uhalnd School with Sustainable Materials | Exterior Wall: wood fiber insulation board<br>Roof: wood fibre insulation board<br>Exposed Floor: VIP, Mineral Wool | 300<br>300<br>40, 120 | 132 | 672 | 73,500 |
| Variant 6: Uhalnd School with Sustainable Materials 2 | Exterior Wall: straw insulation board<br>Roof: straw insulation board<br>Exposed Floor: VIP, Mineral Wool | 300<br>300<br>40, 120 | 135 | 672 | 71,900 |

During the simulation process, to identify the parameters of the variants, it was impossible to create a model for the KfW 40 energy standard that met all the requirements. This was because the calculated energy amount permissible for a KfW 40 building, while simultaneously meeting the necessary insulation standards of a KfW 40 building, could not be achieved, thereby officially failing to meet the energy standard. This conclusion is based on the results of the reference building, which requires a total of 80.3 kWh/m²a. The reference building was constructed according to the specifications of the GEG. Compared to the reference building, however, the Uhlan school already performs well enough to meet the required energy demand of a KfW standard, even with limited insulation material insulation. The main reasons for this include lower room temperatures during heating, higher room temperatures during cooling, lower or higher system temperatures of the heating and cooling system, and a higher degree of heat recovery from ventilation. Therefore, the Variant 1 KfW 40 was no longer part of the analysis.

## 4.4 Overview of Different Scenarios

For the analysis, seven different scenarios are considered to evaluate the impact of varied system boundaries on the analysis. The first three consider three different amounts of GHGs in the electricity mixes.  In the first one, the amount of GHGs in the German electricity mix remains constant from the values of 2024. In the second one, the amount of GHGs in the electricity mix decreases dynamically to be in line with the targets set out by the Government of the Federal Republic of Germany (cf. 2.4.2). To also account for a slower decarbonising grid, the third scenario, is based on a constant decline in the amount of GHG in the electricity mix. In both scenarios, the electricity mix will be carbon-free by 2045. Scenarios 4 and 5 account for the time value of carbon by discounting future flows of GHGs to a net present value. For scenario 4, a discount rate of 1%, and scenario 5, a discount rate of 2.5% is used (cf. Chapter 2.4.1). OE emissions and EE of Modul C are discounted in the year they occur, while the EE of Modul B is discounted all after 25 years. Furthermore, in the evaluation interface of eLCA, it is impossible to assign the emissions from Phase B to a specific product and, thus, to the exact time of its replacement. Nevertheless, the assumption that all emissions from repair and replacement occur after 25 years is conservative, as future emissions are less heavily weighted due to discounting. Scenario 6 represents a combination of Scenario 2 and 4 to show the influence of overlapping these scenarios. Lastly, in scenario 7, the system boundaries of the LCA are expanded to account for Module D, where benefits beyond the buildings from recycling, reuse and recovery are considered. Table 23 lists all scenarios and how they vary the system boundaries.

**Table 23: Overview of the different expanded system boundaries.**

| Scenarios | Expanded System Boundaries |
|---|---|
| 1 | Base Case, constant GHGs in the electricity mix |
| 2 | GHGs in the electricity mix decline, based on the targets the Government of the Federal Republic of Germany set out. Zero emissions will be reached in 2045. |
| 3 | GHGs in the electricity mix decline constantly until zero emissions are reached in 2045. |
| 4 | Accounts for the time value of carbon by discounting future emissions with 1%. |
| 5 | Accounts for the time value of carbon by discounting future emissions with 2.5%. |
| 6 | Combines the expanded system boundaries of Scenario 2 and 4. |
| 7 | Includes the Moduld D in the LCA |

# 5 Results

In Chapter 5, the results of the LCA for the base case and the variants under different scenarios are presented. First, the base case's performance under various scenarios highlights the impact of expanding the system boundaries. Secondly, the variants are compared to the base case under the different scenarios. Lastly, the energy simulation results are validated by comparing the results to the building physics report, and a sensitivity analysis is conducted to highlight the impact that a possible EPG of the simulation could have on the results.

## 5.1 LCE of the Case Study

Table 24 shows the LCE of the case study in kg$CO_2$-Equ./m². It is divided into the EE of the cost group 300 and 400 and the OE due to the energy demand or the negative emissions from the fed in electricity. The OEs are shown under the assumptions of Scenario 1, where the share of $CO_2$-Equ. emissions in the electricity mix stay constant.

**Table 24: LCE in kgCO2-Equ./m² of the case study divided into EE and OE for a reference study period of 50a.**

| | Calculated values for the construction part (Sum of Modules A1 - A3, B2-B4, C3, C4) | GWP [kgCO2-Equ./m²] |
|---|---|---|
| EE | **Sum of Cost Group 300** | 327,3 |
| | 320 Foundations | 1,7 |
| | 330 Exterior Walls | 161,7 |
| | 340 Interior Walls | 64,4 |
| | 350 Ceilings | 67,7 |
| | 360 Roofs | 31,8 |
| | **Sum of Cost Group 400** | 237,4 |
| | Base Rate | 60,0 |
| | 420 Heat Supply Systems | 17,4 |
| | 430 Ventilation Systems | 1,1 |
| | 440 Power installations | 153,0 |
| | 460 Conveyor systems | 5,9 |
| OE | **Calculated values for the operation Energy demand (B6)** | -226,0 |
| LCE | **Sum** | 338,7 |

More than half of the embodied emissions stem from the CG 300. In it, the sub-CG 330 has the most significant share in the emissions. For CG 330, the amount of insulation material is responsible for most of the emissions. CG 400 is responsible for slightly less than half of the embodied emissions. The biggest emitters are the base rate and the CG 440 power installations. Here, the number of PV modules is the dominating factor. The two largest emitting sub-CG 330 and 440 combined are responsible for more than 50% of all embodied emissions. At the same time, it greatly influences the operational energy demand as the insulation material reduces the amount needed, and the number of PV modules increases the amount fed in electricity. Therefore, varying these design choices can show whether the trade between EE and OE is worth it.

Figure 5-1 looks at which LCA Phase the embodied emissions arise.

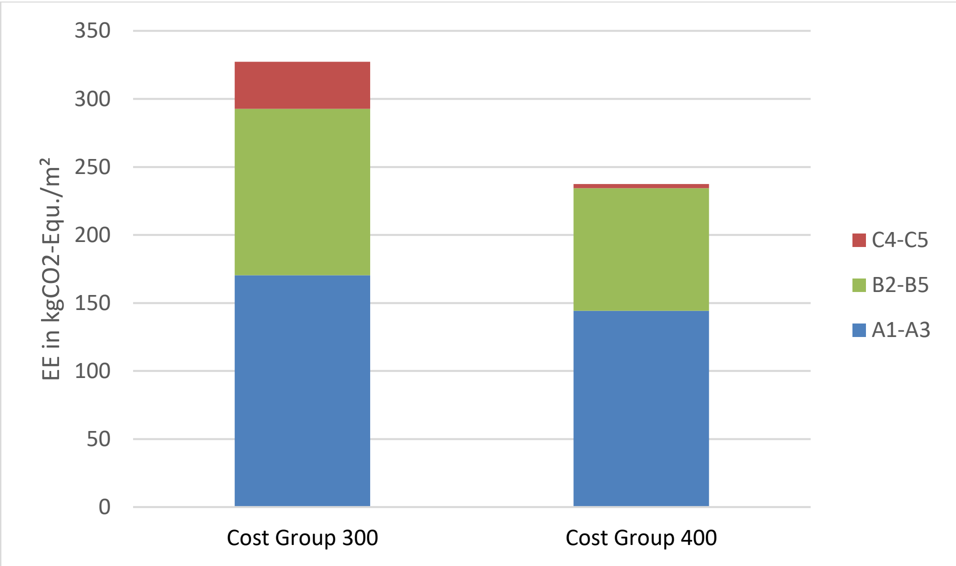



**Figure 5-1: The EE in kgCO2-Equ./m² distribution for the different life stages of CG 300 & 400 for a reference study period of 50a.**

For CG 300, 52% stem from phases A1-A3, 37% from phases B2-B5, and 11% from phases C4-C5. Similarly, in CG 400, 60% arise in phases A1-A3, while in phases B2-B5, 37% and only a marginal amount of 3% in phases C4-C5. However, it should be mentioned that for CG 400, 84% of the emissions of phases B2-B5 come from the PV modules alone. A further investigation into the PV modules showed that the modules mounted on the rooftop are responsible for 84.5 % of the solar capacity and also hold a similar share of 83.9% share in the surface area. As the roof-mounted modules are slightly more efficient than the façade mounted modules, the façade modules were exchanged first if the solar capacity was lowered in the variants.

Looking at the LCE emissions under the scenarios presented in Chapter 4.4, negative GHGs from the operational stage are reduced as either the amount of substitutional emissions is reduced or future emissions are discounted to a present value. Figure 5-2 shows the development of the LCE if the German electricity mix decarbonises.

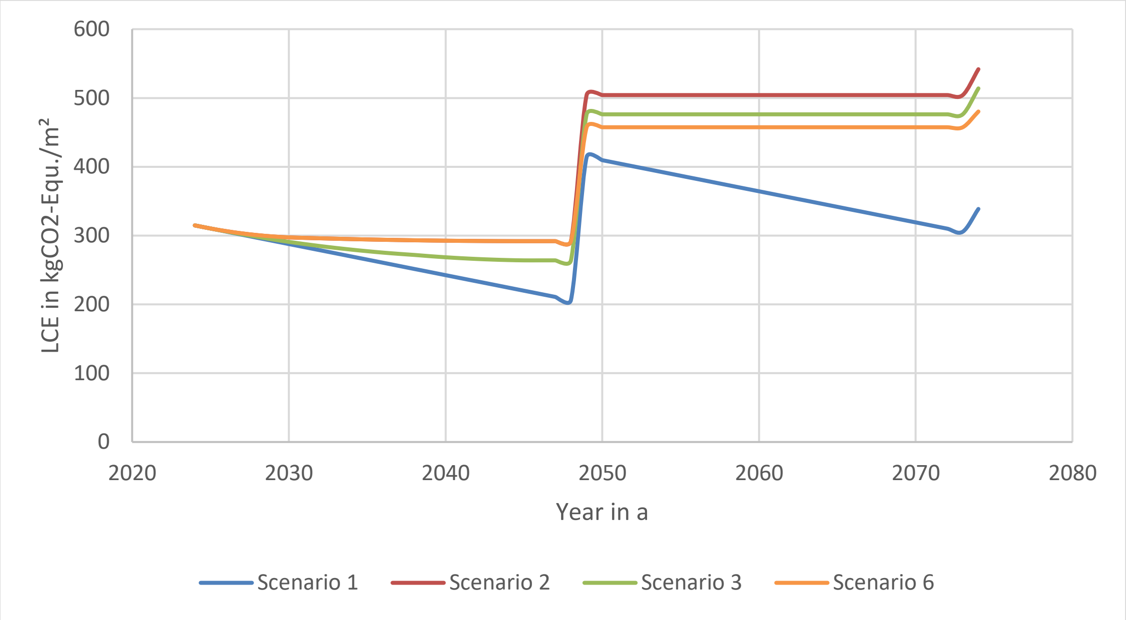



**Figure 5-2: Development of the LCE of the base case under scenarios with a decarbonising electricity mix 1, 2, 3, and 6 over a reference study period of 50a.**

Each scenario starts with the EE from Phase A. Then, the LCEs decrease depending on the substituted $CO_2$-Equ. emissions from the electricity mix achieved through the excess electricity produced. Depending on the scenario path, the achieved value varies. After 25 years, all emissions from Phases B2-B4 are accounted for together. The resulting sudden increase in LCE is seen. Since no further substitution occurs in Scenarios 2, 3, and 4, the LCE remains at the same level. Lastly, the $CO_2$-Equ. emissions from Phase C occur after 50 years, leading to a slight increase in LCE.

Figure 5-2 highlights how sensitive the final LCEs are depending on how much CO2-Equ. emissions remain in the electricity grid. The LCEs increased from Scenario 1 to Scenario 2 by almost 160%. Furthermore, the weighting of future emissions seen in scenario six only has a marginal effect compared to the other scenarios with a decarbonising grid, as only the emissions from Modules B and C are discounted.

This marginal effect of the time value of carbon on the LCE can also be observed in Scenarios 4 and 5 (cf. Figure 5-3).

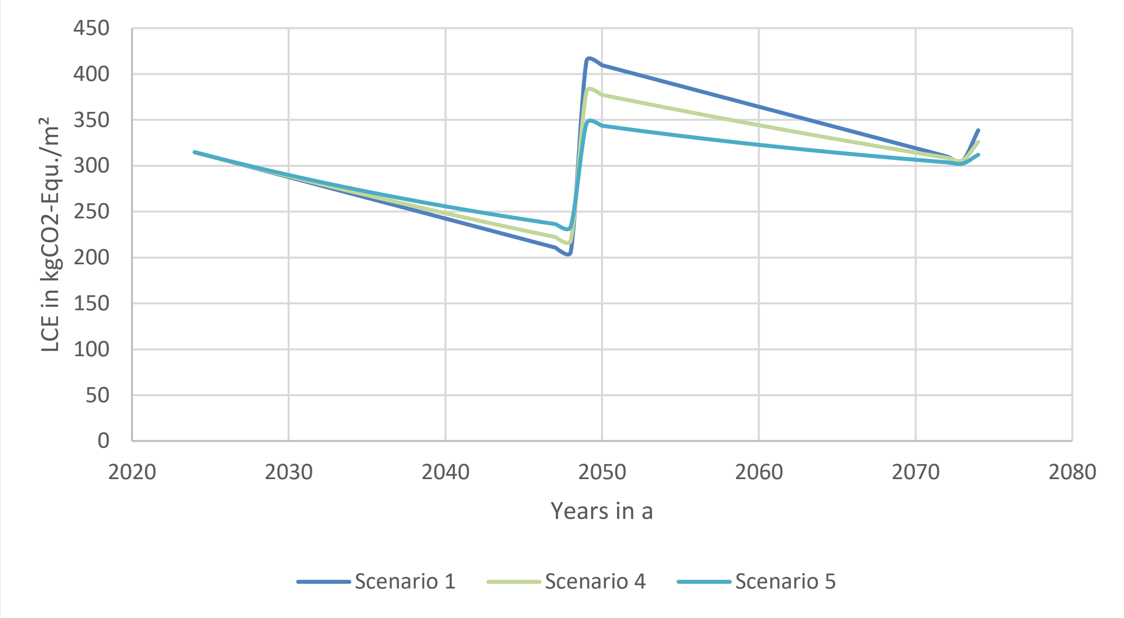



**Figure 5-3: Development of the LCE of the base case under scenarios with different discount rates (Scenario 1 0%, Scenario 4 1%, Scenario 5 2.5%) over a reference study period of 50a.**

The LCE at the end of the reference period of 50 years only differs between Scenario 1 and 5 by 8%. This raises the question of whether the time value of carbon is essential in a study period of 50 years, where the majority of emissions happen right at the beginning. At the same time, hypothesis 3c is proven to be true. The expansion of the system boundaries to include the time value of carbon results in different LCE. However, as the impacts of scenarios 4, 5, and 6 are so small, they were neglected in the variant study.

## 5.2 Comparision of the Life Cycle Emissions of Different Variants under various scenarios

Table 24 shows the EE and the percental change compared to the base case of the different variants. Only the sub-cost groups 330, 350, 360 and 440 are shown, as they are the only ones affected by the varied design decisions. Variants 2-4 have the same thickness and type of insulation material. Therefore, the EE does not change between these variants. Compared to the base case, the EE of CG 300 for variants 2-4 are 15% lower. The amount of energy demand the solar modules cover affects the EE of CG 400. Depending on the total surface area of the PV modules, the EE changes between 0-36% for Variants 2-4.

**Table 25: Embodied Emissions of the different Variants and how they change compared to the base case for a reference study period of 50a. Only the cost groups in which a change occurs are shown.**

| | Base Case | Variant 2 | | Variant 3 | | Variant 4 | | Variant 5 | | Variant 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | GWP [kgCO2-Equ./m²] | GWP | Chang in % | GWP | Chang in % | GWP | Chang in % | GWP | Chang in % | GWP | Chang in % |
| **CG 300** | 327,3 | 279,6 | -15 | 279,6 | -15 | 279,6 | -15 | 335,8 | +3 | 248 | -24 |
| 330 | 161,7 | 138 | -15 | 138 | -15 | 138 | -15 | 160,4 | -1 | 94,3 | -42 |
| 350 | 67,7 | 50,5 | -25 | 50,5 | -25 | 50,5 | -25 | 67,7 | 0 | 67,7 | -0 |
| 360 | 31,8 | 25 | -21 | 25 | -21 | 25 | -21 | 41,6 | +31 | 19,8 | -38 |
| **CG 400** | 237,4 | 152,9 | -36 | 217,6 | -8 | 237,4 | - | 237,4 | - | 237,4 | - |
| 440 | 153 | 85,6 | -44 | 133,2 | -13 | 153 | - | 153 | - | 153 | - |

Variants 5-6 reflect the change in the insulation material type. The EE of CG 300 increased for variant 5 even though wood fibres are considered a more sustainable insulation material. The higher emissions can be explained by the fact that the service life of wood fibres is only 40 years compared to EPS insulation, which has a service life of 50 years. This means the wood fibres must be exchanged once during the study period. In the case of the straw insulation in variant 6, the embodied emissions decreased by 24%.

The changed design decisions of variants 2-6 consequently affected the yearly energy demand and, therefore, the OE. The increase or decrease in the annual electricity demand and electricity production of the different variants are shown in Figure 5-4.

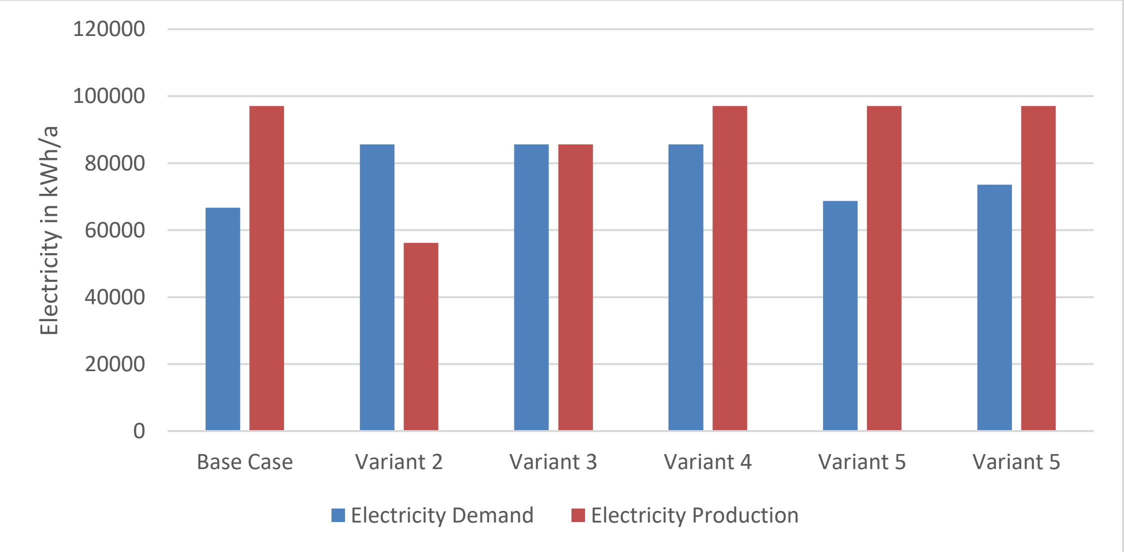



**Figure 5-4: Comparison of the base case and variants' yearly electricity demand and production in kWh/a.**

The lower energy standard of a passive house and the consequential rise in energy demand is reflected in variants 2-4. Similarly, the switch to renewable insulation materials also increased the energy demand of the building (cf. variant 5-6). Fewer PV modules decrease the on-site electricity production (cf. Variant 2-4). The effect of these changes can be seen in Figure 5-5. Here, the LCE emissions of all variants under scenario 1 are shown.

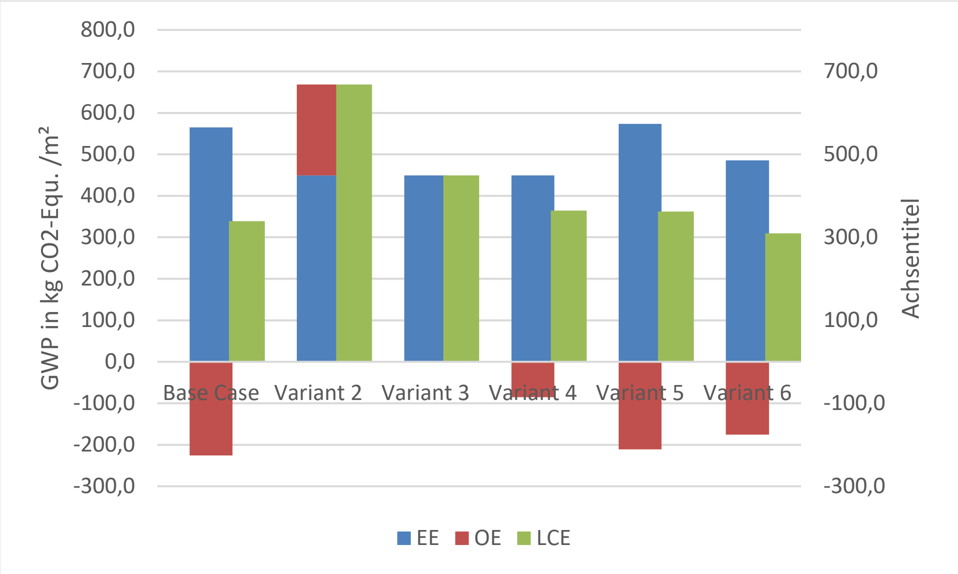



**Figure 5-5: Comparison of the EE, OE and LCE of the different variants in scenario 1 in a reference study period of 50 years.**

In this scenario, only the LCE of variant 6 is lower than that of the base case. This is because the emission credit for the feed-in electricity outweighs the increased EE compared to variants 2-4; however, scenario 1 assumes a constant level of $CO_2$-Euq.-emissions in the electricity mix for the study period. This might overemphasise the impact of the fed-in electricity. Nothlesse, a lower energy standard did not result in fewer GHG emissions under the specified system boundaries, disproving hypothesis 1. To further investigate the influence of a change in the system boundaries, the two scenarios that account for the influence of a changing electricity mix are considered (cf. Figure 5-6).

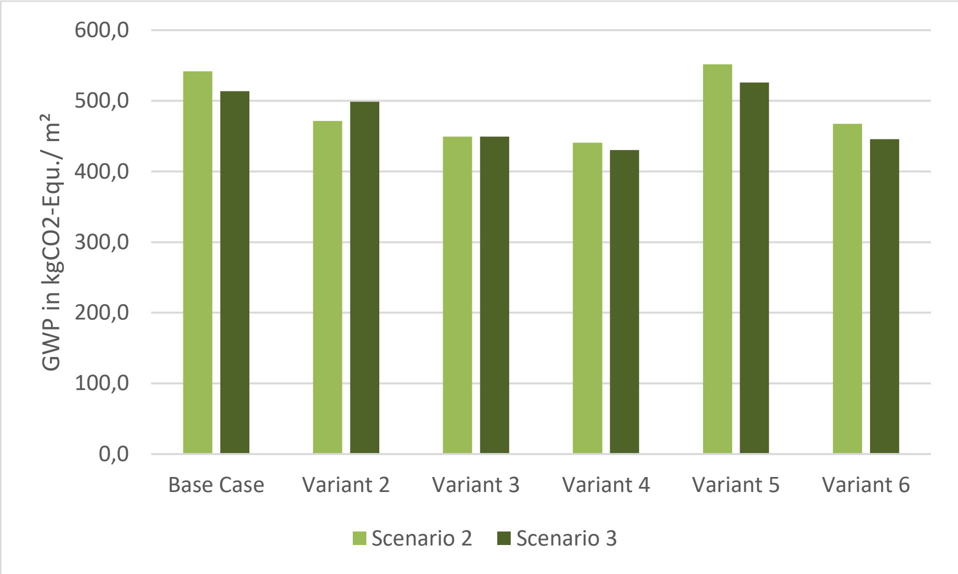



**Figure 5-6: Development of the LCE of each Variant for Scenarios 2-3 with a reference study period of 50 years.**

In both scenarios (2-3) with a decarbonising grid variant 4, the school building with a passive house heating demand and an overall plus energy building performance outperforms all other variants. Compared to the base case, the LCE of the building decreased by 19% in scenario 2 and 16% in scenario 3. The best performance of variant 4 was achieved under scenario 3 with a constant decrease in CO2-Euq.-emissions in the energy mix. Generally, the plus energy building standards performed better under a slower decarbonising grid as they got more negative carbon emissions for their fed-in electricity. A closer look at the differences between the LCE of variants 3 and 4 under scenario 2 shows that quicker decarbonisation of the electricity mix results in a smaller difference in LCE compared to the scenario with slower decarbonisation. This raises the question of whether the zero-energy building could outperform the plus-energy building at a later starting time of the analysis. Nonetheless, variants 2-4 show that an increased onsite energy production results in lower LCEs. Furthermore, they show that an increase in energy demand can lead to lower LCEs, as variants 2-4 outperformed the base case for scenarios 2 and 3, provided that the increase in energy demand goes along with a decrease in EEs. This highlights again how important system boundaries are for the results of an analysis of the LCE, confirming hypothesis 3b.

This is highlighted by variants 5 and 6. Though using sustainable building materials increased the energy demand of the building, they did not lower the LCEs in the case of variant 5 as the EEs did not decrease. For variant 6, this was the case, resulting in overall lower LCEs. Therefore, a general claim that natural building materials like wood fibres or straw decrease the overall LCE can not be observed, disproving hypothesis 2.

## 5.3 Comparision of the Life Cycle Emissions of Different Variants with the Inclusion of Phase D

In scenario 7, phase D of a LCA is included in the calculations of the LCE. For the comparison, the best-performing variant of the passive house standards, variant 4, and the best-performing variant of the sustainable building materials, variant 6, are included. Figure 5-7 shows the LCE under scenarios 1-3.

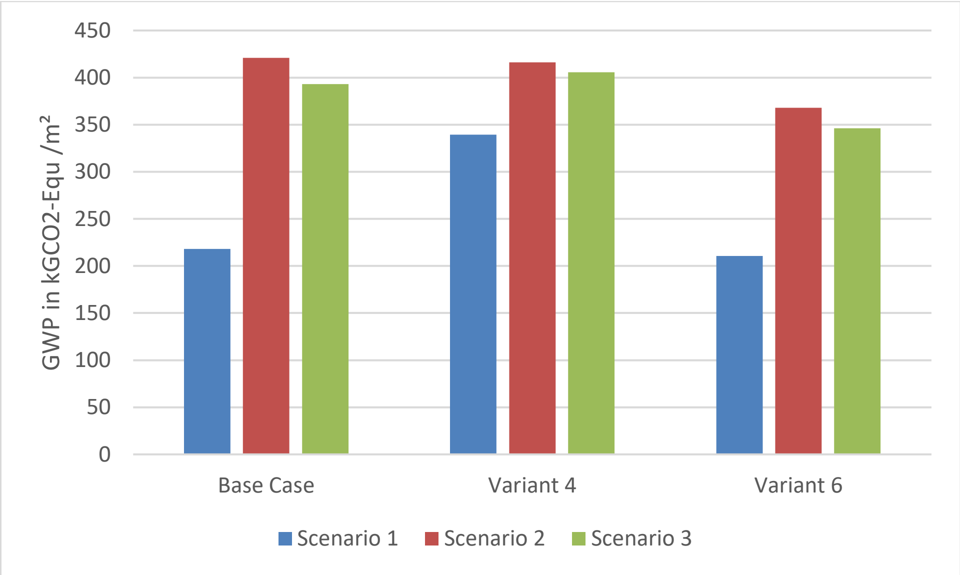



**Figure 5-7: Development of the LCEs of different Variants, including module D, under various scenarios with a reference study period of 50 years**

If the system boundaries of the LCA are expanded to include phase D, the overall best-performing design standard is variant 6 with the sustainable insulation material straw. Overall, all building standards emit fewer GHGs if module D is included. This shows the potential of a circular material stream through the reusing or recycling of building materials on the LCE of the building industry. However, challenges remain in data availability, methodological consistency, and integrating these assessments into practical building processes and a concept that would ensure reuse in the future (cf. chapter 2.2.2.2). Therefore, hypothesis 3a, “The results vary depending on the inclusion of Module D in the LCA”, is proven to be true.

## 5.4 Validation of Results

The result of the dynamic energy simulation carried out in this work is validated by comparing the result with the result from the energy simulation conducted by the building physicist (cf. Table 26). The different input parameters can explain the remaining differences in the results. In the simulation conducted in HB, the weather files from a nearby weather station of the school building were used. In contrast, the building physics report assumed a general reference climate for Germany. Furthermore, the energy demand of the appliances and corresponding exhaust heat are part of the HB simulation. This results in varying heating and cooling demands. The missing cooling energy demand in the building physics report can result from the modelled night cooling that the author could not simulate in HB. Furthermore, the cooling of the building is also used to increase or replenish the thermal energy of the geothermal prob field. It should, therefore, not be allocated to a cooling demand. Nonetheless, the cooling demand represented in the HB simulation will be considered, especially as this might increase as the climate gets more extreme.

**Table 26: Comparison of the different results of the energy simulations divided into the different outputs.**

| | Final energy demand Heating [kWh/m²a] | Final energy demand Hot Water [kWh/m²a] | Final energy demand Lighting [kWh/m²a] | Final energy demand Cooling [kWh/m²a] | Final energy demand Total [kWh/m²a] |
|---|---|---|---|---|---|
| Report by the building physicist | 7.3 | 1.8 | 1.3 | 0.0 | 10.3 |
| Honeybee | 7.7 | 1.8 | 1.2 | 0.75 | 11.4 |
| Deviation | 5.2% | 0.0% | 7.3% | - | 9.6% |

The energy demand for the appliances could not be validated by comparing the simulation as the report to show compliance with the GEG does not require it. However, as these values are derived from observed values, they are assumed to fit the installation.

The PV-simulation results were validated using the rule of thumb that 1kWp represents 1000 kWh/a. With an installed capacity of 100 kWp in the case study, the simulation results of 97,069.0 kWh/a seem plausible.

The LCA Results of the base scenario were compared to the results of a study that examined different building standards and their embodied emissions and found that renovations to higher energy standards result in 3-8 kg$CO_2$-Equ./(m²a). The base case emits 11.29 kg$CO_2$-Equ./(m²a). This difference can be explained by the far lesser heating demand of the base case scenario (7.7 kWh/m²a) compared to the refurbished buildings in the study (35-141 kWh/m²a), resulting in using more insulation material and the amount of solar panels used. Additionally, the technical building equipment is balanced in the LCA through conservative estimations in this analysis, e.g. the base rate from QNG. (Mahler et al., 2019)

# 5.5 Sensitivity Analysis

To investigate the sensitivity of the analysis stemming from the energy demand during the operational use of the building and incorporate the performance gap between BES and actual energy demand of the building, the result of the BES of the base case and the variant 4, as it was the overall best-performing variant, is changed. The energy demand increases from the original results by 34%, representing the identified average deviation between BES and actual performance (cf. Chapter 2.3.3)

Figure 5-8 shows the increase in LCE of the base case and variant 4 under scenario 1 if an EPG of 34% is included in the analysis.

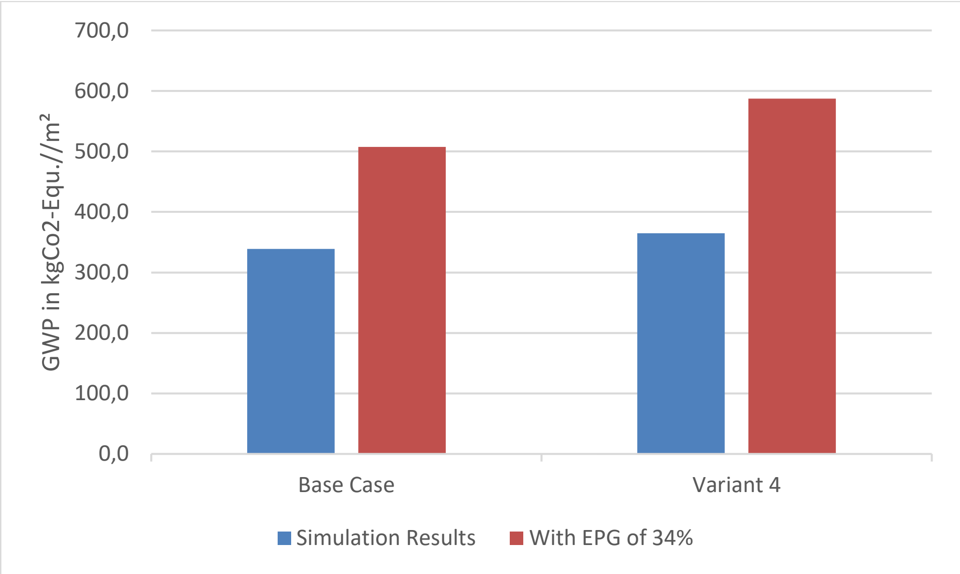



**Figure 5-8: Increase in LCE if the actual energy demand increases by 34% compared to the simulation over a study period of 50 years for scenario 1.**

The LCE of the base case increased by 50%, while in the case of variant 4, the LCE increased by 61%. This highlights the sensitivity of the analysis. The higher increase in variant 4 can be attributed to the fact that after the increased energy demand, the building is no longer a plus energy building and, therefore, no longer generates negative emissions by feeding electricity into the grid. However, even if an EPG of 34% is considered, variant 4 outperforms the base case in scenarios 2 and 3 (cf. Figure 5-9).

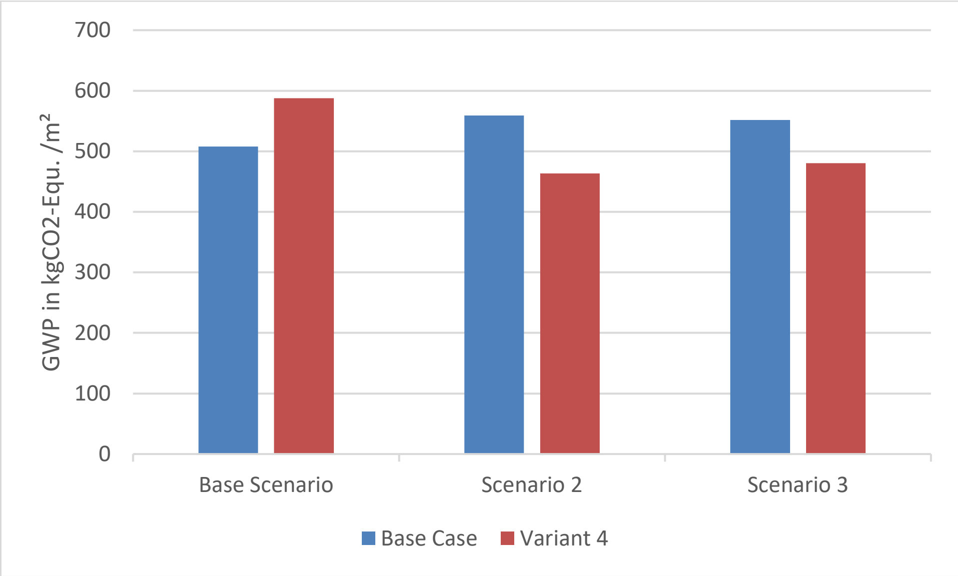



**Figure 5-9: Different LCE under scenarios 1-3 with the consideration of the EPG of 34% over a study period of 50 years.**

# 6 Limitations

During the application of the methodology, several limitations were identified. First, the impact of important design decisions regarding the technical building equipment, like the HVAC system or building automation, could not be quantified. This had two main reasons. The HVAC system could only be represented in limited detail in the building simulation, as this would have required more extensive modifications to the program's programming language. At the same time, only a limited number of datasets for technical building equipment are available in the ÖKOBAUDAT database, which means that the changes could not be transferred to the LCA. However, the energy simulation of the reference building showed that the HVAC has an enormous influence on the energy demand of a building. At the same time, the EEs of CG 400 are significant. Representing this influence on the LCE could be a field of future research, provided that the limitations identified in this research can be overcome.

Second, additional limitations due to the chosen database influenced the results. Only one option is available for the technical building equipment datasets. This often represents a worst-case scenario for the environmental impacts of the technical building equipment, which could result in an overestimation in the analysis. Furthermore, no generic or valid EPD was available for new insulation materials like straw insulation or vacuum insulations. They must be added to ensure these EPDs are created using the same stringent methods as other EPDs in the ÖKOBAUDAT. This is especially important because the potential of straw insulation to reduce the LCE is high.

Third, the analysis only included the GWP. To ensure that these design changes also positively affect other indicators, the goal and scope of the LCA should be expanded. Only then is it possible to claim that certain design decisions result in the most sustainable building.

Fourth, during the quantity estimation to create the building catalogue, the dimensions of the building components were not always clearly defined. For example, sections to identify all new structural components' heights were missing, so assumptions had to be made. If a building model had been created, human errors or assumptions would have been smaller. Consequently, the quantity estimation would have a higher resolution, and the resulting emissions could have been estimated more accurately. Accurate building models are necessary for future research or, in general, to better predict LCE in the building industry.

Lastly, the analysis was conducted on a single school building with extremely low energy demand and specific climate conditions. Different building types and climate conditions should be considered to validate the results and make them applicable in other contexts.

# 7 Conclusion

To reduce the negative impact of the building sector on the environment, the EU introduced legislation that focused on reducing the buildings' operational emissions. However, this entails increased embodied emissions from the increase in materials, potentially leading to higher life cycle emissions. Hence, this research aimed to identify energy standards and design decisions that would lead to lower life cycle emissions based on the example of a refurbished school building. The research question was: *Which building energy standard and design decisions, accounting for embodied and operational emissions, offer the most effective pathway toward sustainable construction in non-residential buildings?*

The study presented the theoretical background to asses LCE by first defining LCE, highlighting the impact energy standards and design decisions can have on the LCE and introducing LCA, a method to assess potential environmental emissions of buildings. The theoretical background established key system boundaries for the LCA and how varying them can influence the final results. Chapters 3 and 4 define the system boundaries of the LCA and how it is applied based on the research. In Chapter 5, the results of the variant study are shown under different scenarios. In scenario one, where the energy demand of the building is converted with a constant amount of GHG emissions into the OE, the variant with straw insulation but a slightly higher energy demand than the base case achieves the lowest LCE. In scenarios two and three, the decarbonisation of the German electricity mix is considered to reflect future developments. The plus energy building with a passive house heating demand performs best here. However, the base case is also outperformed by the variants with only a passive house standard and lower on-site energy production. The influence of the time value of carbon is only minimal on the LCE. One reason is that most emissions occur at the beginning of the construction and are therefore not discounted, especially in scenarios with a decarbonising energy grid. The second reason is that the discount rates of 1% and 2.5% are quite low. Lastly, with the inclusion of module D, the impact of sustainable building materials and the general potential of reducing the LCE of buildings by reusing or recycling building materials is shown. In this last scenario, variants 4 and 6 outperformed the base case; in this scenario, variant 6 has the lowest LCE. To ensure that the results can be applied even if the simulation results from the energy simulation differ from the actual performance, a sensitivity analysis with the average performance gap of an energy simulation was conducted. It showed that even though the results of the LCA are highly sensitive to changes in the energy simulation, the overall results do not change. Variants 4 and 6 still outperformed the base case.

Based on the results obtained from this study, the answer to the research question and the validity of the hypothesis is as follows: No clear energy standard can be singled out as the best-performing energy standard as it highly depends on the system boundaries chosen, validating hypothesis 3, and the actual energy demand that has to be covered by the on-site energy production. Furthermore, changing to sustainable building materials results in higher energy demand but does not automatically lower the LCE of a building, disproving hypothesis 2. Nonetheless, two key findings concerning design decisions could be identified:

1) All scenarios showed that the amount of insulation materials used in the base case to reduce the energy losses of the building was too much as a lower energy performance can potentially produce less LCE. Highlighting that when evaluating the performance of a building, embodied emissions should also be considered and validating hypothesis 1.

2) The analysis showed that the full potential of onsite energy production should be harnessed as all variants with the same energy demand performed better the more PV modules were installed.

Therefore, to reduce the building sector's GHG, future legislation and designers should also consider the embodied emissions when evaluating the sustainability of a new building.

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# Appendix

**Appendix A: Component Catalogue starting with building materials, list of windows, list of doors and technical building equipment.**

Bauteilkatalog Uhlandschule

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| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge [m2] Menge Neu [m³] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| Untergeschoss UG1 - UG2 | | | | | | | | | | |
| 330 | | Aussenwande | | UG 2 Auffullung | Auffullung UG 2 | | | | Schnitt: 1A_21012SCC_G; Grundriss: 1A_21001UG2_D | |
| 330 | 336 | | | | Stahlbeton | 0,4 | | Transportbeton C25/30; Bewehrungsstahl (de) | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | | Aussenwände | | UG 1 | | | | | Schnitt: 1A_21012SCC_G; Grundriss: 1A_21002UG1-1_I; Detail Sockel:1A_22561_B | |
| 330 | 331 | | | | Stahlbeton | 0,4 | | Transportbeton C25/30; Bewehrungsstahl (de) | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | 335 | | | | Noppenbahn | 0,01 | 180,6 | PE-Noppenfolie zur Abdichtung (de) | | |
| 330 | 335 | | | | Perimeterdämmung | 0,12 | 180,6 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 335 | | | | Bitumöser Anstrich | 0,0025 | 180,6 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 350 | | Boden UG-Erdreich | H 2.01 Treppenhalle Fußboden gegen Erdreich | U180, U103, U181 | Treppenhalle West, Abstellraum, Flur | | 39 | | Bodenaufbauten 1A_21092UG1-1_A; Detail 1A_22680_0 | |
| 350 | 352 | | | | Anstrich | 0,001 | 39,0 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 39,0 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 39,0 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | VIP Akustik EVP | 0,028 | 39,0 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 350 | 352 | | | | Epoxidharzdampfbremse | 0,001 | 39,0 | Dampfbremse PE (de) | | |
| 350 | 351 | | | | Stahlbeton C30/37 | 0,12 | 39,0 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 350 | 353 | | | | Kies | 0,05 | 39,0 | --- | | |
| 350 | | Boden UG-Erdreich | H 2.02 Flur Fußboden gegen Erdreich | U105, U107, U 106 | Elektroraum | | 44,6 | | Bodenaufbauten 1A_21092UG1-1_A; Detail 1A_22680_0 | |
| 350 | 352 | | | | Anstrich | 0,001 | 44,6 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 44,6 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 44,6 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | Leichtausgleich | 0,094 | 44,6 | Zementmortel (de) | | |
| 350 | 352 | | | | Bitumdampfbremse | 0,002 | 44,6 | Dampfbremse PF | | |
| 350 | 352 | | | | Fliesen | 0,01 | 44,6 | Steinzeugfliesen glasiert (de) | | |
| 350 | 352 | | | | Kleber | 0,003 | 44,6 | '--- | | |
| 350 | 351 | | | | Stahlbeton C30/37 | 0,12 | 44,6 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 350 | 353 | | | | Kies | 0,05 | 44,6 | '--- | | |
| 350 | | Boden UG-Erdreich | H 2.04 Flur Fußboden gegen Erdreich | U184 | Flur | | 19,9 | | Bodenaufbauten 1A_21092UG1-1_A; Detail 1A_22680_0 | |
| 350 | 352 | | | | Kunststeinplatte | 0,02 | 19,9 | --- | | |
| 350 | 352 | | | | Mörtelbrett | 0,03 | 19,9 | --- | | |
| 350 | 351 | | | | Stahlbeton | 0,12 | 19,9 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 350 | 353 | | | | Kies Ausleichschicht | 0,05 | 19,9 | --- | | |
| 350 | | Boden UG-Erdreich | H 2.01 Treppenhalle Fußboden gegen Erdreich | U109, U110 | Lager UG | | 80,8 | | Bodenaufbauten 1A_21092UG1-1_A; Detail 1A_22680_0 | |
| 350 | 352 | | | | Anstrich | 0,001 | 80,8 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 80,8 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | TSD Folie (Weberfloor 4955) | 0,003 | 80,8 | Dampfbremse PE (de) ; Glasvlies (de); Dampfbremse PE (de) | | |
| 350 | 352 | | | | Leichtausgleich | 0,002 | 80,8 | Zementmörtel (de) | | |
| 350 | 352 | | | | Epoxidharzdampfbremse | 0,001 | 80,8 | Dampfbremse PE (de) | | |
| 350 | 351 | | | | Stahlbeton C30/37 | 0,12 | 80,8 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 350 | 353 | | | | Kies | 0,05 | 80,8 | --- | | |
| 350 | | Boden UG 2-Erdreich | | U201-U205 | Anstrich | | 94,5 | | Bodenaufbauten 1A_21091UG2_A | |
| 350 | 352 | | | | Anstrich | 0,001 | 94,5 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| Erdgeschoss | | | | | | | | | | |
| 330 | | Aussenwände | nicht vorhanden | Aussenwand Nord Gang | Dämmung mit Isovver Unter Fenster | | | | Grundriss:1A_21003EG-1_S ; Schnitt: BB, DD ; Detail Sockel | Höhe = Raumhöhe + Hälfte der Decken/Böden |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 56,7 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Isover Ultimate | 0,2 | 56,7 | Mineralwolle (Fassaden-Dämmung) | | |
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,2 | 12,771 | Extrudierter Polystyrol Dammstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,175 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Innenausbau | 0,08 | 56,7 | --- | | Nicht abgebildet in eLCA. Keine Ahngaben zum Innenausbau |
| 330 | | Aussenwände | AW mit Lockplate | Aussenwand - WC West | Regelfassade - Fassade West | | | | Grundriss 1A_21003EG-1_S; Ansicht BB; Schnitte CC | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 41,6 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Vakuumsandwichelement VIP/EPS | 0,09 | 41,6 | externes EPD: EPD-POR-20200138-IBC1-DE | | |

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Maximilian Schleicher

| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge [m2] Menge Neu [m³] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,29 | 7,535 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 331 | | | | Beton C20/25 | 0,3 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 43,1 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW mit Lockplate | Aussenwand - Klassenzimmer Textils Werken | Regelfassade - Fassade West | | | | Grundriss 1A_21003EG-1_S; Ansicht BB; Schnitte CC | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 26,4 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Vakuumsandwichelement VIP/EPS | 0,09 | 26,4 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,29 | 5,650 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 26,4 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwande | | Aussenwand Süd TRH West | Regelfassade - Süd TRH West | | | | IBP_Sanierung Uhlandschule;Grundriss: 1A_21003FG-1_S; Schnitt EE; Sockel Details | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 16,1 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Mineralwolle | 0,29 | 16,1 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,29 | 3,346 | Extrudierter Polystyrol Dammstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,175 | | Mauerziegel (ungefullt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | | Aussenwände | | Aussenwand Süd | - Süd (Dämmung Abwechselnd) | | | | IBP_Sanierung Uhlandschule; Grundriss: 1A_21003EG-1_S; Ansicht: 1A_21022AS_I; Schnitt CC; Fenster Details | |
| 330 | 335 | | | | Alublech Farbe RAL9003 | 0,04 | 7,5 | Aluminiumblech (de) | | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 22,4 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Isover Ultimate | 0,2 | 10,7 | Mineralwolle (Fassaden-Dämmung) | | |
| 330 | 335 | | | | WDVS mit Steinwolle | 0,2 | 11,6 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 335 | | | | Sockeldammplatte WDVS | 0,29 | 4,93 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Beton | 0,3 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | 336 | | | | Putz | 0,01 | 22,4 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | | Aussenwand Süd | Regelfassade - Süd | | | | IBP_Sanierung Uhlandschule;Grundriss: 1A_21003EG-1_S; Schnitt BB; Sockel Details | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 88,28 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Mineralwolle | 0,27 | 88,28 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,2 | 27,48 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefullt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putz | 0,01 | 88,28 | Gipsputz (innen) (de) | | |
| 330 | | Stutzen | nicht vorhanden | Stutzen Überdachung Süd | Stutzen Überdachung | | | | Grundriss: 1A_21003EG-1_S; Schnitt: BB, DD; FF; Detail Sockel | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 30,1 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Mineralwolle | 0,08 | 30,1 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 331 | | | | Beton | 0,4 | | Kunstharzputz (de) | | Gesamt Stahlbeton Neu Außenwände Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 340 | | Innenausbau | | WC | Innenausbau | | | | Wandaufbauten: 1A_21103EG1_0; Schnitt CC; EE; BB; DD; FF; GG | |
| 340 | 345 | | | | 2-lagig RIGIDUR (Gipsphaserplatten) | 0,15 | 116,6 | Gipsfaserplatte (10mm) (de) | Trockenbauarbeiten: 10 SR Wibau Revisionsakte | |
| 340 | 342 | | | | Fließen | 0,01 | 95,7 | Steinzeugfliesen glasiert (de) | Detail Fließenspiegel: 1A_22640_D | |
| 340 | 345 | | | | Anstrich | 0,0025 | 63,5 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | | Innenausbau | | Anstrich + Putz | Anstrich und Putz Wande Innenseite (Blau Markiert) | | | | Wandaufbauten: 1A_21103EG1_0; Schnitt CC; EE; BB; DD; FF; GG | |
| 340 | 345 | | | | Anstrich | 0,0025 | 486,0 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | 345 | | | | Putz | 0,01 | 486,0 | Gipsputz (innen) (de) | | |
| 340 | | Innenausbau | | Anstrich | Anstrich Füllung (Orang Markiert) | | | | Wandaufbauten: 1A_21103EG1_0; Schnitt CC; EE; BB; DD; FF; GG | Stütze Achse G; Wand Textiles Werken |
| 340 | 341 | | | | Anstrich | 0,0025 | 71,6 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | | Innenausbau | | Metallerkleidung | Mettalverkleidung (Pink) | | | | Wandaufbauten: 1A_21103EG1_0; Schnitt DD; | |
| 340 | 341 | | | | Beschichtung Metall | 0,0025 | 10,1 | Aluminiumblech (de) | | |
| 342 | | Innenwand | | Klassenräume, Vvorraum Musik | Hybridwand RIGIDUR, 1GKB (grün) | | | | Wandaufbauten: 1A_21103EG1_0; Schnitt CC, EE, BB, DD, FF, GG | |
| 350 | 352 | | | | GKB | 0,015 | 17,3 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 3452 | 342 | | | | Rigidur (einlagig) | 0,075 | 17,3 | Gipsfaserplatte (10mm) (de) | | |
| 350 | | Decken UG-EG | H 3.01 Fußboden unterkellert - Flur WC West | 081 WC Flur | WC Flur | | 7,4 | | Bodenaufbauten 1A_21093EG1_A; Detail 1A_22680_0 | |
| 350 | 352 | | | | Fliesen | 0,01 | 7,4 | Steinzeugfliesen glasiert (de) | | |

Bauteilkatalog Uhlandschule

Maximilian Schleicher

| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge [m2] / Menge Neu [m²] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 350 | 352 | | | | Kleber | 0,003 | 7,4 | Fliesenkleber (de) en | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 7,4 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 7,4 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,012 | 7,4 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 351 | | | | Stb-Flachdecke | 0,25 | 7,4 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | |
| 350 | 353 | | | | Mineralwolle | 0,12 | 7,4 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | | Decken UG-EG | H 3.02 Fußboden unterkellert - Klasse | 002 - 007 Klassenräume - 083, 084 Flur | Klassenräume über Keller | | 225,6 | | Bodenaufbauten 1A_21093EG1_A; Detail 1A_22680_0 | |
| 350 | 352 | | | | Linoleum | 0,003 | 225,6 | Linoleum (de) | | |
| 350 | 352 | | | | Kleber | 0,002 | 225,6 | Kleber für Gipsplatten (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 225,6 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | TSD Folie (Weberfloor 4955) | 0,001 | 225,6 | Dampfbremse PE (de) ; Glasvlies (de); Dampfbremse PE (de) | | |
| 350 | 352 | | | | Leichtausgleich | 0,002 | 225,6 | Zementmörtel (de) | | |
| 350 | 351 | | | | Remy-Decke | 0,29 | 225,6 | --- | | |
| 350 | 353 | | | | Mineralwolle | 0,12 | 225,6 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 353 | | | | Rigips CD6027 | 0,027 | 225,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Rigips CD6027 | 0,027 | 225,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Gipsplatten DFR | 0,04 | 225,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | | Decken UG-EG | H 3.04 Fußboden unterkellert - Feuchträume West | 070-074 WC Schler, Putzraum | WC | | 27,5 | | Bodenaufbauten 1A_21093EG1_A; Detail 1A_22680_0 | |
| 350 | 352 | | | | Fliesen | 0,01 | 27,5 | Steinzeugfliesen glasiert (de) | | |
| 350 | 352 | | | | Kleber | 0,003 | 27,5 | Fliesenkleber (de) en | | |
| 350 | 352 | | | | Abdichtung | 0,001 | 27,5 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 27,5 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,012 | 27,5 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 351 | | | | Stb-Flachdecke | 0,25 | 27,5 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | |
| 350 | 353 | | | | Mineralwolle | 0,12 | 27,5 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | | Decken UG-EG | H 3.05 Fußboden gegen Erdreich - Werkräume | 008 Lehrküche, 009 NR Lehrküche | Küche | | 118,9 | | Bodenaufbauten 1A_21093EG1_A; Detail 1A_22680_0 | |
| 350 | 352 | | | | Fliesen | 0,01 | 118,9 | Steinzeugfliesen glasiert (de) | | |
| 350 | 352 | | | | Kleber | 0,002 | 118,9 | Fliesenkleber (de) en | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 118,9 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | VIP Akustik EVP | 0,028 | 118,9 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 350 | 352 | | | | TSD Folie (Weberfloor 4955) | 0,003 | 118,9 | Dampfbremse PE (de) ; Glasvlies (de); Dampfbremse PE (de) | | |
| 350 | 352 | | | | Leichtausgleich | 0,003 | 118,9 | Zementmörtel (de) | | |
| 350 | 351 | | | | Stahlbeton | 0,12 | 118,9 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 350 | 353 | | | | Kies | 0,05 | 118,9 | --- | | |
| 350 | | Decken UG-EG | H 3.07 Fußboden gegen Erdreich - Feuchträume | 075-079 WC Bereich Ost | WC Bereich Ost | | 21,8 | | Bodenaufbauten 1A_21093EG2_D; Detail 1A_22680_0 | |
| 350 | 352 | | | | Fliesen | 0,01 | 21,8 | Steinzeugfliesen glasiert (de) | | |
| 350 | 352 | | | | Kleber | 0,003 | 21,8 | Fliesenkleber (de) en | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 21,8 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 21,8 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | VIP Akustik EVP | 0,028 | 21,8 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 350 | 352 | | | | TSD (Isover) | 0,012 | 21,8 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 352 | | | | Leichtausgleich | 0,004 | 21,8 | Zementmörtel (de) | | |
| 350 | 352 | | | | Epxidhardampfbremse | 0,001 | 21,8 | Dampfbremse PE (de) | | |
| 350 | 351 | | | | Stahlbeton | 0,12 | 21,8 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 350 | 353 | | | | Kies | 0,05 | 21,8 | --- | | |
| 350 | | Decken UG-EG | H 3.08 Fußboden unterkellert - Klasse | 001 Textiles Werken | Flachdecke | | 69,9 | | Bodenaufbauten 1A_21093EG1_A; Detail 1A_22680_0 | |
| 350 | 352 | | | | Linoleum | 0,003 | 69,9 | Linoleum (de) | | |
| 350 | 352 | | | | Kleber | 0,002 | 69,9 | Kleber für Gipsplatten (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 69,9 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 69,9 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,02 | 69,9 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 351 | | | | Stahlbeton | 0,25 | 69,9 | Transportbeton C30/37 (de), Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 350 | 353 | | | | Mineralwolle | 0,12 | 69,9 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | | Decken UG-EG | H 3.09 Fußboden gegen Erdreich - Werkräume | 010 Technik, 011 Maschinenraum, 012 Technik | Werkräume | | 208 | | Bodenaufbauten 1A_21093EG2_D; Detail 1A_22680_0 | |
| 350 | 352 | | | | Fliesen | 0,01 | 208,0 | Steinzeugfliesen glasiert (de) | | |

3

Maximilian Schleicher

| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge [m2] Menge Neu [m²] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 350 | 352 | | | | Kleber | 0 | 208,0 | Fliesenkleber (de) en | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 208,0 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 208,0 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | VIP Akustik EVP | 0,028 | 208,0 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 350 | 352 | | | | TSD (Isover) | 0,012 | 208,0 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 352 | | | | Epxidhardampfbremse | 0,001 | 208,0 | Dampfbremse PE (de) | | |
| 350 | 351 | | | | Stahlbeton | 0,12 | 208,0 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände Berechnung siehe Tabelle: Übersicht-Flächen Volumen Neu |
| 350 | 353 | | | | Kies | 0,05 | 208,0 | --- | | |
| | | | | | | | | | | |
| 423 | 423 | Heizdecken | | Heizdecke EG | | | | | Deckenspiegel: 1A_2173EG 1F | |
| 423 | 423 | | | | Paneel Heizdecke MCI | 0,02 | 67,7 | Extern über Sockelbetrag QNG | | |
| 423 | 423 | | | | Paneel Heizdecke Rehau | 0,02 | 123,1 | Extern über Sockelbetrag QNG | | |
| Erdgeschoss Anbau | | | | | | | | | | |
| 330 | | Aussenwände | AW Hochlochziegel EPS Putz | Aussenwand Nord West-Gang | Regelfassade - Dämmung Hart | | | | Wandaufbauten: 1A_21003EG-2_P; Schnitt: 1A_21013SDD_H | Höhe = Raumhöhe + Hälfte der Decken/Böden |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 150,8 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Wärmedämmung Hart Neu EPS | 0,3 | 150,8 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flachen Volumen neu |
| 330 | 336 | | | | Putz | 0,01 | 163,8 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW mit Lockplate | Aussenwand - West | Aussenwand West | | | | Grundriss: 1A_21003EG-2_P; Schnitt: 1A_21018SHH_F; Ansicht Ost | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 44,8 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Vakuumsandwichelement VIP/EPS | 0,09 | 44,8 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 44,8 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | | Aussenwand Süd | Regelfassade - Süd | | | | IBP_Sanierung Uhlandschule;Grundriss: 1A_21003EG-2_P; Schnitt AA, HH; Sockel Details | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 57,0 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Mineralwolle | 0,27 | 57,0 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 335 | | | | Sockeldammplatte WDVS | 0,2 | 12,825 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flachen Volumen neu |
| 330 | 336 | | | | Putz | 0,01 | 57,0 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | | Aussenwand Süd TRH | Regelfassade - Süd TRH | | | | IBP_Sanierung Uhlandschule;Grundriss: 1A_21003EG-2_P; Schnitt AA, HH; Sockel Details | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 8,8 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Mineralwolle | 0,23 | 8,8 | Mineralwolle (Fassaden-Dammung) (de) | | |
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,2 | 1,940 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,175 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | | Aussenwände | AW Hochlochziegel EPS Putz | Aussenwand Nord TRH Ost | Regelfassade - Dämmung Hart | | | | Grundriss: 1A_21003EG-2_P; Schnitt: 1A_21018SHH_F, 1A_21010SAA_H; Detail Sockel | Höhe = Raumhöhe + Hälfte der Decken/Böden |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 17,0 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Wärmedämmung Hart Neu EPS | 0,3 | 17,0 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | 335 | | | | Sockeldammplatte WDVS | 0,2 | 2,134 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,175 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putz | 0,01 | 18,2 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | nicht vorhanden | Aussenwand Nord Gang | Dämmung mit Isovver Unter Fenster | | | | Grundriss: 1A_21003EG-2_P; Schnitt: 1A_21018SHH_F, 1A_21010SAA_H; Detail Sockel | Höhe = Raumhöhe + Hälfte der Decken/Böden |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 25,6 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Isover Ultimate | 0,2 | 25,6 | Mineralwolle (Fassaden-Dämmung) | | |
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,2 | 7,274 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,175 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flachen Volumen neu |
| 330 | 336 | | | | Innenausbau | 0,08 | 25,6 | --- | | Nicht abgebildet. Keine Ahngaben zum Innenausbau |
| 330 | | Stützen | nicht vorhanden | Stützen Überdachung Süd | Stützen Überdachung | | | | Grundriss: 1A_21003EG-2_P; Schnitt: 1A_21018SHH_F, 1A_21010SAA_H; Detail Sockel | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 14,7 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Mineralwolle | 0,08 | 14,7 | Mineralwolle (Fassaden-Dammung) (de) | | |
| 330 | 331 | | | | Beton | 0,4 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen Volumen Neu |
| 340 | | Innenausbau | | Anstrich + Putz | Anstrich und Putz Wände Innenseite (Blau Markiert) | | | | Wandaufbauten:1A_21103EG2_0, Schnitt: 1A_21018SHH_F | |
| 340 | 345 | | | | Anstrich | 0,0025 | 279,6 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | 345 | | | | Putz | 0,01 | 279,6 | Gipsputz (innen) (de) | | |

4

 

| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge (m2) Menge Neu [m³] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 340 | | Innenausbau | | WC | Innenausbau | | | | Wandaufbauten: 1A_21103EG2_0; Schnitt: 1A_21018SHH_FSchnitt: 1A_21018SHH_F | |
| 340 | 345 | | | | 2-lagig RIGIDUR | 0,15 | 43,6 | Gipsfaserplatte (10mm) (de) | Trockenbauarbeiten: 10 SR Wibau Revisionsakte | |
| 340 | 342 | | | | Fließen | 0,01 | 96,8 | Steinzeugfliesen glasiert (de) | | |
| 423 | | Heizdecken | | Heizdecke EG | | | | | Deckenspiegel: 1A_2173EG-1F | |
| 423 | 423 | | | | Paneel Heizdecke MCI | 0,02 | 10,8 | Extern über Sockelbetrag QNG | | |
| 423 | 423 | | | | Paneel Heizdecke Rehau | 0,02 | 68,0 | Extern über Sockelbetrag QNG | | |
| 1. Obergeschoss | | | | | | | | | | |
| 330 | | Aussenwände | AW Hochlochziegel EPS Putz | Aussenwand Nord West-Gang | Regelfassade - Dämmung Hart | | | | Wandaufbauten: 1A_21104OG1-1_0; Schnitt: 1A_21013SDD_H | Höhe = Raumhöhe + Hälfte der Decken/Böden |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 150,8 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Wärmedämmung Hart Neu EPS | 0,3 | 150,8 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Ubersicht Flächen Volumen neu |
| 330 | 336 | | | | Putz | 0,01 | 163,8 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | | Aussenwand Nord West - Gang | Brandstreifen | | | | Wandaufbauten: 1A_21104OG1-1_0, Schnitt: 1A_21013SDD_H, 1A_21016SGG_F, 1A_21014SEE_G | Der Brandstreifen Zieht sich an der Gesamten Außenwand Nord mit EPS entlang auch überhalb der Fenster |
| 330 | 336 | | V1 / AW01. | | Mineralwolle WLG 033 | 0,01 | 13,0 | Mineralwolle (Fassaden-Dammung) (de) | | |
| 330 | 331 | | V1 / AW01. | | Kuntzhartzputz | 0,015 | 13,0 | Kunstharzputz (de) en de | | |
| 330 | | Aussenwände | AW mit Lockplate | Aussenwand - WC/TRH | Regelfassade - WC/TRH | | | | Wandaufbauten: 1A_21104OG1-1_0; Ansicht BB | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 49,0 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Vakuumsandwichelement VIP/EPS | 0,09 | 49,0 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Ubersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmortel | 0,01 | 49,0 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW mit Lockplate | Aussenwand - Klassenzimmer West | Regelfassade - Fassade West | | | | Wandaufbauten: 1A_21104OG1-1_0; Ansicht BB | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 35,9 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Vakuumsandwichelement VIP/EPS | 0,09 | 35,9 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmortel | 0,01 | 35,9 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | | Aussenwand Süd | Regelfassade - Süd (Dämmung Abwechselnd) | | | | IBP_Sanierung Uhlandschule; 1A_21104OG1-1_0(Wandaufbauten);; Ansicht: 1A_21022AS_I; Schnitte AA-FF; Fenster Details | |
| 330 | 442 | | | | PV-Anlage | | | Photovoltaiksystem 1000 kWh/m2*a ohne Stromgutschrift (de) | | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 151,9 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Isover Ultimate | 0,2 | 74,0 | Mineralwolle (Fassaden-Dämmung) | | |
| 330 | 335 | | | | WDVS mit Steinwolle | 0,2 | 77,9 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 331 | | | | Beton | 0,3 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | 336 | | | | Putz | 0,01 | 151,9 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwande | | Aussenwand - Ausbesserung | Ausbesserung Aussenwand | | | | Übersicht Flachen Volumen Neu | |
| 330 | 337 | | | | Stahlbeton C20/25 | 0,3 | | Transportbeton C25/30 (de), Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 340 | | Innenausbau | | WC | Innenausbau | | | | Wandaufbauten: 1A_21104OG1-1_0; Schnitt CC; | |
| 340 | 345 | | | | 2-lagig RIGIDUR | 0,15 | 84,9 | Gipsfaserplatte (10mm) (de) | Trockenbauarbeiten: 10 SR Wibau Revisionsakte | |
| 340 | 342 | | | | Fließen | 0,01 | 118,5 | Steinzeugfliesen glasiert (de) | | |
| 340 | 342 | | | | Anstrich | 0,0025 | 30,8 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | | Innenausbau | | Anstrich + Putz | Anstrich und Putz Wande Innenseite (Blau Markiert) | | | | Wandaufbauten: 1A_21104OG1-1_0, Schnitt: 1A_21013SDD_H.pdf | |
| 340 | 345 | | | | Anstrich | 0,0025 | 724,5 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | 342 | | | | Putz | 0,01 | 724,5 | Gipsputz (innen) (de) | | |
| 340 | | Innenausbau | | Anstrich | Anstrich Füllung (Orang Markiert) | | | | Wandaufbauten: 1A_21104OG1-1_0, Schnitt: 1A_21013SDD_H.pdf | |
| 340 | 341 | | | | Anstrich | 0,0025 | 24,8 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | | Innenausbau | | Metallerkleidung | Mettalverkleidung (Pink) | | | | Wandaufbauten:1A_21104OG1-1_0; Schnitte: 1A_21014SEE_G, 1A_21014SGG_F | |
| 340 | 341 | | | | Beschichtung Metall | 0,0025 | 36,7 | Aluminiumblech (de) | | |
| 350 | | Innenwand | | Klassenräume, Vvorraum Musik | Hybridwand RIGIDUR, 1GKB (grün) | | | | Wandaufbauten: 1A_21104OG1-1_0, Schnitte: 1A_21014SEE_G, 1A_21014SGG_F | |
| 350 | 352 | | | | GKB | 0,015 | 12,4 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 352 | | | | Rigidur (einlagig) | 0,075 | 12,4 | Gipsfaserplatte (10mm) (de) | | |

 

| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge (m2) Menge Neu [m²] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 340 | | Innenwand | | Neues Mauerwerk & Beton | | | | | Wandaufbauten: 1A_21104OG1-1_0; Schnitte: 1A_21014SEE_G; 1A_21014SGG_F; Übersicht_Flächen_Volumen_Neu | |
| 340 | 341 | | | | Mauerwerk | 0,2 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 340 | 341 | | | | Beton C20/25 | 0,2 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 350 | | Decken EG-1.OG | H 4.01 & H4.02 Fußboden WC M / W West | WC M / W West, Putzraum (170, 172, 173, 174,171,181) | Fußboden WC | | 35,1 | | 3.6 Bodenaufbauten; 1A_21094OG1-1_A; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Fließen | 0,01 | 35,1 | Steinzeugfliesen glasiert (de) | | |
| 350 | 352 | | | | Kleber | 0,003 | 35,1 | Fliesenkleber (de) en | | |
| 350 | 352 | | | | Abdichtung | 0,001 | 35,1 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 35,1 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 35,1 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,012 | 35,1 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 351 | | | | Ripppendecke | 0,33 | 35,1 | --- | | |
| 350 | 353 | | | | Mineralwolle | 0,05 | 35,1 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 353 | | | | Grundprofiel Rigips CD 60/2 | 0,027 | 35,1 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Tragproofil Rigips | 0,027 | 35,1 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Glasroc F | 0,015 | 35,1 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | GKBi | 0,0125 | 35,1 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | | Decken EG-1.OG | H 4.03 Fußboden Klassenräum | Klassenräume 101-114 | Klassenräume | | 713,3 | | 3.6 Bodenaufbauten; 1A_21094OG1-1_A & 1A_21094OG1-2_A; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Linoleum | 0,003 | 713,3 | Linoleum (de) | | |
| 350 | 352 | | | | Kleber | 0,002 | 713,3 | Kleber für Gipsplatten (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 713,3 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 713,3 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,012 | 713,3 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 351 | | | | Ripppendecke | 0,33 | 713,3 | --- | | |
| 350 | 353 | | | | Mineralwolle | 0,05 | 713,3 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 353 | | | | Grundprofiel Rigips CD 60/2 | 0,027 | 713,3 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Tragproofil Rigips | 0,027 | 713,3 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Glasroc F | 0,015 | 713,3 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | | Decken EG-1.OG | H 4.05 Flur | Flur 180, 183-184; 188 | Flur 1.OG | | 227,6 | | 3.6 Bodenaufbauten; 1A_21094OG1-1_A & 1A_21094OG1-2_A; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Linoleum | 0,003 | 227,6 | Linoleum (de) | | |
| 350 | 352 | | | | Kleber | 0,002 | 227,6 | Kleber für Gipsplatten (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 227,6 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 227,6 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,02 | 227,6 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 352 | | | | Leichtausgleich | 0,01 | 227,6 | Zementmörtel (de) | | |
| 350 | 351 | | | | Ripppendecke | 0,33 | 227,6 | --- | | |
| 350 | 353 | | | | Mineralwolle | 0,05 | 227,6 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 353 | | | | Grundprofiel Rigips CD 60/2 | 0,027 | 227,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Tragproofil Rigips | 0,027 | 227,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Glasroc F | 0,015 | 227,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 423 | | Heizdecken | | Heizdecken zwischen EG - 1.OG | | | | | Deckenspiegel: 1A_21073EG-1_F | |
| 423 | 423 | | | | Paneel Heizdecke MCI | 0,02 | 66,6 | Extern über Sockelbetrag QNG | | |
| 423 | 423 | | | | Paneel Heizdecke Rehau | 0,02 | 140,1 | Extern über Sockelbetrag QNG | | |
| 1. Obergeschoss Anbau | | | | | | | | | | |
| 330 | | Aussenwände | AW Hochlochziegel EPS Putz | Aussenwand Nord West-Gang | Regelfassade - Dämmung Hart | | | | Grundriss: 1A_21004OG1-2_N; Schnitt: 1A_21010SAA_H | Höhe = Raumhöhe + Hälfte der Decken/Böden |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 72,1 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Wärmodämmung Hart Neu EPS | 0,3 | 72,1 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putz | 0,01 | 72,1 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW mit Lockplate | Aussenwand - Ost | Aussenwand Ost | | | | Grundriss: 1A_21004OG1-2_N; Schnitt: 1A_21010SAA_H; Ansicht Ost | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 46,4 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Vakuumsandwichelement VIP/EPS | 0,09 | 46,4 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |

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Maximilian Schleicher

| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge (m2) Menge Neu [m²] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 330 | 336 | | | | Putzmortel | 0,01 | 46,4 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | | Aussenwand Süd | Regelfassade - Süd (Dämmung Abwechselnd) | | | | Grundriss: 1A_21004OG1-2_N; Schnitt: 1A_21010SAA_H; Ansicht Süd | |
| 330 | 442 | | | | PV-Anlage | | | Photovoltaiksystem 1000 kWh/m2*a ohne Stromgutschrift (de) | | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 55,8 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Isover Ultimate | 0,2 | 41,3 | Mineralwolle (Fassaden-Dammung) | | |
| 330 | 335 | | | | WDVS mit Steinwolle | 0,2 | 14,5 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 331 | | | | Beton | 0,3 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | 336 | | | | Putz | 0,01 | 55,8 | Gipsputz (innen) (de) | | |
| 340 | | Innenausbau | | Anstrich + Putz | Anstrich und Putz Wände Innenseite (Blau Markiert) | | | | Wandaufbauten: 1A_21104OG1-2_0; Schnitt: 1A_21010SAA_H; | |
| 340 | 345 | | | | Anstrich | 0,0025 | 271,5 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | 345 | | | | Putz | 0,01 | 271,5 | Gipsputz (innen) (de) | | |
| 340 | | Innenausbau | | Anstrich | Anstrich Füllung (Orang Markiert) | | | | Wandaufbauten: 1A_21104OG1-2_0; Schnitt: 1A_21010SAA_H; | |
| 340 | 341 | | | | Anstrich | 0,0025 | 147,9 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | | Innenausbau | | Metallerkleidung | Mettalverkleidung (Pink) | | | | Wandaufbauten: 1A_21104OG1-2_0; Schnitt: 1A_21010SAA_H; | |
| 340 | 341 | | | | Beschichtung Metall | 0,0025 | 8,3 | Aluminiumblech (de) | | |
| 340 | | Innenwand | | Klassenräume, Vorraum Musik | Hybridwand RIGIDUR, 1GKB (grün) | | | | Wandaufbauten: 1A_21104OG1-2_0; Schnitt: 1A_21010SAA_H; | |
| 340 | 342 | | | | GKB | 0,015 | 74,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 340 | 342 | | | | Rigidur (einlagig) | 0,075 | 74,6 | Gipsfaserplatte (10mm) (de) | | |
| 3410 | | Innenwand | | Neues Mauerwerk & Beton | | | | | Wandaufbauten: 1A_21104OG1-2_0; Schnitt: 1A_21010SAA_H; | |
| 340 | 341 | | | | Mauerwerk | 0,2 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 360 | | Dach | Bauteilaufbaut Dach EPS 031 | Anbau Dach Ausrichtung Süd | Dach Süd | | | | Grundriss: 1A_21004OG1-2_N; Schnitt: AA, HH; Details Dach: 1A_22601_E; Schichtaufbau IBF | |
| 360 | 442 | | | | PV-Anlage | | | Photovoltaiksystem 1000 kWh/m2*a ohne Stromgutschrift (de) | 1A_21304LP4_B | 119 Module 16,4 kWp |
| 360 | 363 | | | | Dachabdichtungsbahn Polyolefin | 0,01 | 246,8 | TPO/FPO Dach-und Dichtungsbahn (de) | | |
| 360 | 363 | | | | neoTopDach EPS 031 | 0,3 | 246,8 | EPS-Hartschaum (Rohdichte 15 kg/m³) | | |
| 360 | 363 | | | | Dampfsperre | 0,0025 | 246,8 | Dampfbremse PE (de) | | |
| 360 | 361 | | | | Remy-Decke | 0,2 | 246,8 | --- | | |
| 360 | 364 | | | | Gipskartonplatte | 0,02 | 246,8 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool | | |
| 360 | 364 | | | | Mineralwolle | 0,05 | 187,3 | Mineralwolle (Boden-Dämmung) (de) | 1A_21074OG1-2_F | |
| 360 | 364 | | | | Glasroc F | 0,015 | 187,3 | Gipsbauplatte (Feuerschutz; 12,5mm) | 1A_21074OG1-2_F | |
| 360 | 364 | | | | Akustikdecke | 0,02 | 187,3 | Nicht dargestellt. Kein Datensatz vorhanden | 1A_21074OG1-2_F | |
| 423 | 423 | | | | Paneel Heizdecke Rehau | 0,02 | 78,3 | Extern über Sockelbetrag QNG | 1A_21074OG1-2_F | |
| 423 | 423 | | | | Paneel Heizdecke MCI | 0,02 | 5,5 | Extern über Sockelbetrag QNG | 1A_21074OG1-2_F | |
| 360 | | Dach | Bauteilaufbaut Dach EPS 031 | Anbau Dach Ausrichtung Nord | Dach Nord | | | | Grundriss: 1A_21004OG1-2_N; Schnitt: AA, HH; Details Dach: 1A_22601_F; Schichtaufbau IBF | |
| 360 | 363 | | | | Dachabdichtungsbahn Polyolefin | 0,0025 | 133,3 | TPO/FPO Dach-und Dichtungsbahn (de) | | |
| 360 | 363 | | | | neoTopDach EPS 031 | 0,2 | 133,3 | EPS-Hartschaum (Rohdichte 15 kg/m³) | | |
| 360 | 363 | | | | Dampfsperre | 0,0025 | 133,3 | Dampfbremse PE (de) | | |
| 360 | 361 | | | | Remy-Decke | 0,2 | 133,3 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool | | |
| 360 | 364 | | | | Gipskartonplatte | 0,02 | 133,3 | Dampfbremse PE (de) | | |
| 360 | 364 | | | | Mineralwolle | 0,05 | 88,5 | Mineralwolle (Boden-Dämmung) (de) | 1A_21074OG1-2_F | |
| 360 | 364 | | | | Glasroc F | 0,015 | 88,5 | Gipsbauplatte (Feuerschutz; 12,5mm) | 1A_21074OG1-2_F | |
| 360 | 364 | | | | Akustikdecke | 0,02 | 88,5 | Nicht dargestellt. Kein Datensatz vorhanden | 1A_21074OG1-2_F | |
| 423 | 423 | | | | Paneel Heizdecke MCI | 0,02 | 38,2 | Extern über Sockelbetrag QNG | 1A_21074OG1-2_F | |
| 423 | | Heizdecken | | Heizdecke zwischen EG-1.OG | | | | | Deckenspiegel: 1A_21073EG-2_H | |
| 423 | 423 | | | | Paneel Heizdecke MCI | 0,02 | 10,8 | Extern über Sockelbetrag QNG | | |
| 423 | 423 | | | | Paneel Heizdecke Rehau | 0,02 | 36,3 | Extern über Sockelbetrag QNG | | |
| 2. Obergeschoss | | | | | | | | | | |
| 330 | | Aussenwände | AW Hochlochziegel EPS Putz | Aussenwand Nord - Gang | Regelfassade - Dämmung Hart | | | | IBP_Sanierung Uhlandschule; 1A:21105OG2_0.dwg (Wandaufbauten) | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 96,8 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Wärmedämmung Hart Neu EPS | 0,3 | 96,8 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefullt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putz | 0,01 | 96,8 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | | Aussenwand Süd | Regelfassade - Süd (Dämmung Abwechselnd) | | | | IBP_Sanierung Uhlandschule; 1A:21105OG2_0.dwg (Wandaufbauten);; Ansicht: 1A_21022AS_I | |
| 330 | 442 | | | | PV-Anlage | | | Photovoltaiksystem 1000 kWh/m2*a ohne Stromgutschrift (de) | | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 142,0 | Kunstharzputz (de) en de | | |

| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge (m2) Menge Neu [m²] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 330 | 335 | | | | Isover Ultimate | 0,2 | 74,0 | Mineralwolle (Fassaden-Dämmung) | | |
| 330 | 335 | | | | WDVS mit Steinwolle | 0,2 | 67,9 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 331 | | | | Beton | 0,3 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | 336 | | | | Putz | 0,01 | 142,0 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW mit Lockplate | Aussenwand - WC/TRH | Regelfassade - WC/TRH | | | | Wandaufbauten: 1A_21105OG2_0 | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 62,2 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Vakuumsandwichelement VIP/EPS | 0,09 | 62,2 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefullt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 62,2 | Gipsputz (innen) (de) | | |
| 340 | | Innenausbau | | WC | Innenausbau | | | | Wandaufbauten: 1A_21105OG2_0 | |
| 340 | 345 | | | | 2-lagig RIGIDUR (Gipsphaserplatten) | 0,15 | 67,9 | Gipsfaserplatte (10mm) (de) | Trockenbauarbeiten: 10 SR Wibau Revisionsakte | |
| 340 | 342 | | | | Fließen | 0,01 | 90,6 | Steinzeugfliesen glasiert (de) | | |
| 340 | 345 | | | | Anstrich | 0,0025 | 21,7 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | | Innenausbau | | Anstrich + Putz | Anstrich und Putz Wände Innenseite (Blau Markiert) | | | | Wandaufbauten: 1A_21105OG2_0, Schnitt: 1A_21013SDD_H.pdf | |
| 340 | 345 | | | | Anstrich | 0,0025 | 798,4 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | 345 | | | | Putz | 0,01 | 798,4 | Gipsputz (innen) (de) | | |
| 340 | | Innenausbau | | Anstrich | Anstrich Füllung (Orang Markiert) | | | | Wandaufbauten: 1A_21105OG2_0, Schnitt: 1A_21013SDD_H.pdf | |
| 340 | 341 | | | | Anstrich | 0,0025 | 249,6 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 340 | | Innenausbau | | Metallerkleidung | Mettalverkleidung (Pink) | | | | Wandaufbauten:1A_21105OG2_0; Schnitte: 1A_21014SEE_G; 1A_21014SGG_F | |
| 340 | 341 | | | | Beschichtung Metall | 0,0025 | 17,3 | Aluminiumblech (de) | | |
| 340 | | Innenwand | | Klassenräume, Vvorraum Musik | Hybridwand RIGIDUR, 1GKB | | | | Wandaufbauten:1A_21105OG2_0; Schnitte: 1A_21014SEE_G; 1A_21014SGG_F | |
| 340 | 342 | | | | GKB | 0,015 | 91,8 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 340 | 342 | | | | Rigidur | 0,075 | 91,8 | Gipsfaserplatte (10mm) (de) | | |
| 340 | | Innenwand | | Neues Mauerwerk & Beton | | | | | Wandaufbauten:1A_21105OG2_0; Schnitte: 1A_21014SEE_G; 1A_21014SGG_F | |
| 340 | 341 | | | | Mauerwerk | 0,2 | 58,2 | Mauerziegel (ungefullt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 340 | 341 | | | | Beton C20/25 | 0,2 | 0,7 | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | |
| 350 | | Decken 1.OG-2.OG | H 5.04 Fußboden Klassenräume | Klassenräume | Linolium Boden & Abgehängte Decke | | 442,1 | | 3.6 Bodenaufbauten; 1A_21095OG2_A; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Linoleum | 0,003 | 442,1 | Linoleum (de) | | |
| 350 | 352 | | | | Kleber | 0,002 | 442,1 | Kleber für Gipsplatten (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 442,1 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 442,1 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,012 | 442,1 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 351 | | | | Rippendecke | 0,33 | 442,1 | --- | | |
| 350 | 354 | | | | Mineralwolle | 0,05 | 442,1 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 354 | | | | Glasroc F | 0,015 | 442,1 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 423 | | | | Paneel Heizdecke Rehau | 0,02 | 128,4 | Extern über Sockelbetrag QNG | Deckenspiegel: 1A_21074OG1-1_F | |
| 350 | | Decken 1.OG-2.OG | H 5.03 Flure, Treppenhalle West | Flure, Treppenhalle West | Linoleum Boden & Abgehängte Decke | | 153,4 | | 3.6 Bodenaufbauten; 1A_21095OG2_A; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Linoleum | 0,003 | 153,4 | Linoleum (de) | | |
| 350 | 352 | | | | Kleber | 0,002 | 153,4 | Kleber für Gipsplatten (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 153,4 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 153,4 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | Trittschalldämmung | 0,02 | 153,4 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 352 | | | | Leichtausgleich | 0,01 | 153,4 | Zementmörtel (de) | | |
| 350 | 351 | | | | Ripppendecke | 0,33 | 153,4 | --- | | |
| 350 | 353 | | | | Mineralwolle | 0,05 | 153,4 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 353 | | | | Glasroc F | 0,015 | 153,4 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 | | |
| 423 | 423 | | | | Panel Heizungdecke MCI | 0,03 | 80,3 | Extern über Sockelbetrag QNG | Deckenspiegel: 1A_21074OG1-1_F | |
| 350 | | Decken 1.OG-2.OG | H 5.02 Fußboden WC Flur | WC Flur | Fußboden WC Flur | | 7,4 | | 3.6 Bodenaufbauten; 1A_21095OG2_A; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Fließen | 0,01 | 7,4 | Steinzeugfliesen glasiert (de) | | |
| 350 | 352 | | | | Kleber | 0,003 | 7,4 | Fliesenkleber (de) en | | |
| 350 | 352 | | | | Abdichtung | 0,001 | 7,4 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 7,4 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 7,4 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,02 | 7,4 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 351 | | | | Ripppendecke | 0,33 | 7,4 | --- | | |
| 350 | 353 | | | | Mineralwolle | 0,05 | 7,4 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 353 | | | | Glasroc F | 0,015 | 7,4 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |

| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge (m2) Menge Neu [m²] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 350 | 353 | | | | GKBi | 0,0125 | 7,4 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | | Decken 1.OG-2.OG | H 5.01 Fußboden WC M / W West | WC M / W West, Putzraum | Fußboden WC | | 27,6 | | 3.6 Bodenaufbauten; 1A_21095OG2_A; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Fließen | 0,01 | 27,6 | Steinzeugfliesen glasiert (de) | | |
| 350 | 352 | | | | Kleber | 0,003 | 27,6 | Fliesenkleber (de) en | | |
| 350 | 352 | | | | Abdichtung | 0,001 | 27,6 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 27,6 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 27,6 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,012 | 27,6 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 351 | | | | Ripppendecke | 0,33 | 27,6 | --- | | |
| 350 | 353 | | | | Mineralwolle | 0,05 | 27,6 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 353 | | | | Glasroc F | 0,015 | 27,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | GKBi | 0,0125 | 27,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 360 | | Dach | Bauteilaufbaut Dach EPS 031 | Dach Ausrichtung Sud | Dach Süd | | | | Grundriss: 1A_21005OG2_R; Schnitt: BB-GG; Details Dach: 1A_22601_E; Schichtaufbau IBF | |
| 442 | 442 | | | | PV-Anlage | | | Photovoltaiksystem 1000 kWh/m2*a ohne Stromgutschrift (de) | 1A_21304LP4_B | 325 Module, 84,5 kWp |
| 360 | 363 | | | | Dachabdichtungsbahn Polyolefin | 0,01 | 613,3 | TPO/FPO Dach-und Dichtungsbahn (de) | | |
| 360 | 363 | | | | neoTopDach EPS 031 | 0,3 | 613,3 | EPS-Hartschaum (Rohdichte 15 kg/m³) | | |
| 360 | 363 | | | | Dampfsperre | 0,0025 | 613,3 | Dampfbremse PE (de) | | |
| 360 | 361 | | | | Remy-Decke | 0,2 | 613,3 | --- | | |
| 360 | 364 | | | | Gipskartonplatte | 0,02 | 613,3 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool | | |
| 360 | 364 | | | | Mineralwolle | 0,05 | 391,8 | Mineralwolle (Boden-Dämmung) (de) | 1A_21075OG2_F | |
| 360 | 364 | | | | Glasroc F | 0,015 | 391,8 | Gipsbauplatte (Feuerschutz; 12,5mm) | 1A_21075OG2_F | |
| 360 | 364 | | | | Akustikdecke | 0,02 | 391,8 | Nicht dargestellt. Kein Datensatz vorhanden | 1A_21075OG2_F | |
| 423 | 423 | | | | Paneel Heizdecke Rehau | 0,02 | 149,2 | Extern über Sockelbetrag QNG | 1A_21075OG2_F | |
| 423 | 423 | | | | Paneel Heizdecke MCI | 0,02 | 26,7 | Extern über Sockelbetrag QNG | 1A_21075OG2_F | |
| 360 | | Dach | Bauteilaufbaut Dach EPS 031 | Dach Ausrichtung Nord | Dach Nord | | | | Grundriss: 1A_21005OG2_R, Schnitt. GG-GG, Details Dach: 1A_22601_E; Schichtaufbau IBF | |
| 360 | 363 | | | | Dachabdichtungsbahn Polyolefin | 0,0025 | 290,6 | TPO/FPO Dach-und Dichtungsbahn (de) | | |
| 360 | 363 | | | | neoTopDach EPS 031 | 0,2 | 290,6 | EPS-Hartschaum (Rohdichte 15 kg/m³) | | |
| 360 | 363 | | | | Dampfsperre | 0,0025 | 290,6 | Dampfbremse PE (de) | | |
| 360 | 361 | | | | Remy-Decke | 0,2 | 290,6 | --- | | |
| 360 | 364 | | | | Gipskartonplatte | 0,02 | 290,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool | | |
| 360 | 364 | | | | Mineralwolle | 0,05 | 196,7 | Mineralwolle (Boden-Dämmung) (de) | 1A_21075OG2_F | |
| 360 | 364 | | | | Glasroc F | 0,015 | 196,7 | Gipsbauplatte (Feuerschutz; 12,5mm) | 1A_21075OG2_F | |
| 360 | 364 | | | | Akustikdecke | 0,02 | 196,7 | Nicht dargestellt. Kein Datensatz vorhanden | 1A_21075OG2_F | |
| 423 | 423 | | | | Paneel Heizdecke Rehau | 0,02 | 10,6 | Extern über Sockelbetrag QNG | 1A_21075OG2_F | |
| 423 | 423 | | | | Paneel Heizdecke MCI | 0,02 | 96,2 | Extern über Sockelbetrag QNG | 1A_21075OG2_F | |
| Treppenhaus 1-2 OG | | | | | | | | | | |
| 330 | | Aussenwände | AW Treppenhaus EPS Putz | Aussenwand - TRH - West | Aussenwand Nord - Regelfassade - Treppenhaus West | | | | IBP_Sanierung Uhlandschule; 1A.21105OG2_0.dwg (Wandaufbauten) | |
| 330 | 335 | | | | Kuntzhartzputz | 0,01 | 38,1 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Warmedammung Hart Neu | 0,3 | 38,1 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flachen Volumen neu |
| 330 | 336 | | | | Putz | 0,01 | 38,1 | Gipsputz (innen) (de) | | |
| 330 | 336 | | | | Anstrich | 0,0025 | 38,1 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 330 | | Aussenwände | AW mit Lockplate | Aussenwand - TRH - West | Aussenwand Typ VIP - TRH | | | | | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 17,8 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Vakuumsandwichelement VIP/EPS | 0,09 | 17,8 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefullt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 17,8 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW mit Isover | Aussenwand - TRH - Mitte | Aussenwand Typ Isover | | | | Grundriss: 1A_21005OG2_R; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G | |
| 330 | 335 | | | | Isover Ultimate | 0,2 | 47,3 | Mineralwolle (Fassaden-Dämmung) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flachen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 47,3 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwande | AW Treppenhaus MW Putz | Aussenwand - TRH - Mitte | Aussenwand Typ Steinwolle | | | | Grundriss: 1A_21005OG2_R; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G | |
| 330 | 335 | | | | Kunsthartzputz | 0,015 | 57,0 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | WDVS Steinwolle | 0,2 | 57,0 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefullt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 57,0 | Gipsputz (innen) (de) | | |

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| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge [m2] Menge Neu [m³] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 330 | | Aussenwande | | Aussenwand - TRH - Mitte | Aussenwand TRH - Nord - EPS | | | | Grundriss: 1A_21005OG2_R; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G | |
| 330 | 335 | | | | Kunsthartzputz | 0,015 | 11,3 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | EPS 031 | 0,3 | 11,3 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | 331 | | | | Beton | 0,3 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 11,3 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | | Aussenwand - TRH - Mitte | Aussenwand TRH - Nord - Steinwolle | | | | Grundriss: 1A_21005OG2_R; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G | |
| 330 | 335 | | | | Kunsthartzputz | 0,015 | 4,0 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | WDVVS Steinwolle | 0,3 | 4,0 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 331 | | | | Beton | 0,3 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 4,0 | Gipsputz (innen) (de) | | |
| 350 | | Decken 1.OG-2.OG | H 5.05 Treppenhalle Zentral | Treppenhalle Mitte | Fußboden Treppenhalle 2.OG | | 84,1 | | 3.6 Bodenaufbauten; 1A_21095OG2_A; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Kunststeinplatten | 0,04 | 84,1 | --- | | |
| 350 | 352 | | | | Mortelbett | 0,05 | 84,1 | --- | | |
| 350 | 351 | | | | Rippendecke | 0,33 | 84,1 | --- | | |
| 350 | 354 | | | | Mineralwolle | 0,05 | 84,1 | Mineralwolle (Fassaden-Dammung) (de) | | |
| 350 | 354 | | | | Glasroc F | 0,015 | 84,1 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| Treppenhaus EG-1OG | | | | | | | | | | |
| 330 | | Aussenwände | AW Treppenhaus EPS Putz | Aussenwand - TRH - West | Aussenwand Nord - Regelfassade - Treppenhaus West | | | | Grundriss: 1A_21004OG1-1_KSchnitt: 1A_21014SEE_G | |
| 330 | 335 | | | | Kuntzhartzputz | 0,01 | 38,8 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Wärmedämmung Hart Neu | 0,3 | 38,8 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putz | 0,01 | 38,8 | Gipsputz (innen) (de) | | |
| 330 | 336 | | | | Anstrich | 0,0025 | 38,8 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 330 | | Aussenwände | AW mit Lockplate | Aussenwand - TRH - West | Aussenwand Typ VIP - TRH | | | | Grundriss: 1A_21004OG1-1_KSchnitt: 1A_21014SEE_G | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 16,4 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Vakuumsandwichelement VIP/EPS | 0,09 | 16,4 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefullt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 16,4 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW mit Isover | Aussenwand - TRH - Mitte | Aussenwand Typ Isover | | | | Grundriss: 1A_21104OG1-1_0; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G | |
| 330 | 335 | | | | Isover Ultimate | 0,2 | 30,6 | Mineralwolle (Fassaden-Dämmung) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 30,6 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW Treppenhaus MW Putz | Aussenwand - TRH - Mitte | Aussenwand Typ Steinwolle | | | | Grundriss: 1A_21104OG1-1_0; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G | |
| 330 | 335 | | | | Kunsthartzputz | 0,015 | 29,2 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | WDVS Steinwolle | 0,2 | 29,2 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefullt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 29,2 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwande | | Aussenwand - TRH - Mitte | Aussenwand TRH - Nord - EPS | | | | Grundriss: 1A_21004OG1-1_K; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G; Broschure Dämmart | |
| 330 | 335 | | | | Kunsthartzputz | 0,015 | 14,7 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | EPS 031 | 0,3 | 14,7 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | 331 | | | | Beton | 0,3 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flachen_Volumen_Neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 14,7 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | | Aussenwand - TRH - Mitte | Aussenwand TRH - Nord - Steinwolle | | | | Grundriss: 1A_21004OG1-1_K; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G; Broschüre Dämmart | |
| 330 | 335 | | | | Kunsthartzputz | 0,015 | 5,3 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | WDVVS Steinwolle | 0,3 | 5,3 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 331 | | | | Beton | 0,3 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 5,3 | Gipsputz (innen) (de) | | |
| 350 | | Decken EG - 1.OG | H 4.07 Treppenhaus Zentral | Treppenhalle Mitte | Fußboden Treppenhalle 1.OG | | 87,8 | | 3.6 Bodenaufbauten; 1A_21094OG1-1_A; 3.10 Details; 1A_22680_0 | |

Bauteilkatalog Uhlandschule

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| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge (m2) Menge Neu [m²] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 350 | 352 | | | | Kunststeinplatten | 0,04 | 87,8 | --- | | |
| 350 | 352 | | | | Mörtelbett | 0,05 | 87,8 | --- | | |
| 350 | 351 | | | | Rippendecke | 0,33 | 87,8 | --- | | |
| 350 | 353 | | | | Mineralwolle | 0,05 | 87,8 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 353 | | | | Glasroc F | 0,015 | 87,8 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Deckenheizsystem | 0,03 | 87,8 | Extern über Sockelbetrag QNG | | |
| 350 | | Decken EG-1.OG | H 4.06 Treppenhaus Ost | Treppenhalle Ost | Fußboden Treppenhalle 1.OG | | 42,4 | | 3.6 Bodenaufbauten; 1A_21094OG1-2_A; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Linoleum | 0,003 | 42,4 | Linoleum (de) | | |
| 350 | 352 | | | | Kleber | 0,002 | 42,4 | Kleber für Gipsplatten (de) | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 42,4 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 42,4 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,012 | 42,4 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 351 | | | | Rippendecke | 0,33 | 42,4 | --- | | |
| 350 | 353 | | | | Mineralwolle | 0,05 | 42,4 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 353 | | | | Glasroc F | 0,015 | 42,4 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | | Decken UG - EG | H 3.06 Fußboden gegen Erdreich | 086 (Ost), 089 (Mitte) Treppenhalle | Fußboden Treppenhalle EG | | 128,5 | | 3.6 Bodenaufbauten; 1A_21039EG2__D; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Fliesen | 0,01 | 128,5 | Steinzeugfliesen glasiert (de) | | |
| 350 | 352 | | | | Kleber | 0,003 | 128,5 | Fliesenkleber (de) en | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 128,5 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 128,5 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | VIP Akustik EVP | 0,028 | 128,5 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 350 | 352 | | | | TSD (Isover) | 0,012 | 128,5 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 352 | | | | Leichtausgleich | 0,01 | 128,5 | Zementmörtel (de) | | |
| 350 | 352 | | | | Epoxidharzdampfbremse | 0,001 | 128,5 | Dampfbremse PE (de) | | |
| 350 | 351 | | | | Stahlbeton C30/37 | 0,12 | 128,5 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 350 | 353 | | | | Kies Ausleichschicht | 0,05 | 128,5 | --- | | |
| 350 | | Decken UG - EG | H 3.03 Fußboden unterkellert - TH | 080 Treppenhalle West | Fußboden Treppenhalle EG | | 47,6 | | 3.6 Bodenaufbauten; 1A_21093EG1__A; 3.10 Details; 1A_22680_0 | |
| 350 | 352 | | | | Fliesen | 0,01 | 47,6 | Steinzeugfliesen glasiert (de) | | |
| 350 | 352 | | | | Kleber | 0,003 | 47,6 | Fliesenkleber (de) en | | |
| 350 | 352 | | | | Calziumsulfatfließenestrich | 0,045 | 47,6 | Calciumsulfatestrich (de) | | |
| 350 | 352 | | | | Trennfolie | 0,001 | 47,6 | PE-Noppenfolie zur Abdichtung (de) | | |
| 350 | 352 | | | | TSD (Isover) | 0,02 | 47,6 | Mineralwolle (Boden-Dämmung) (de) | | |
| 350 | 351 | | | | Remy Decke mit Betondeckung | 0,29 | 47,6 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 350 | 353 | | | | Mineralwolle | 0,12 | 47,6 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 350 | 353 | | | | Rigips CD6027 | 0,027 | 47,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Tragproofil Rigips | 0,027 | 47,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de) | | |
| 350 | 353 | | | | Gipsplatten Typ DFR | 0,04 | 47,6 | GIPSPLATTE NACH DIN EN 520 UND DIN 18180 | | |
| 340 | | Innenwände | MW & Beton Neu | Aufzug Mitte | Aufzug Mitte | | | | Detail Treppenhaus/Aufzug 1A_22554_E.pdf; Excell Tool Übersicht Flächen Neu | |
| 340 | 341 | | | | Beton | 0,2 | 18,4 | Transportbeton C30/37 (de); Bewehrungsstahl (de)) | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 340 | 341 | | | | MW | 0,2 | 76,9 | Mineralwolle (Boden-Dämmung) (de) | | |
| 340 | 342 | | | | Dämmung Perimeterdämmung | 0,12 | 22,3 | olystyrol Dammstoff (XPS) (de) Extrudierter Polystyrol Dammstoff (XPS) (de) | | |
| Treppenhaus EG-UG | | | | | | | | | | |
| 330 | | Aussenwände | AW mit Lockplate | Aussenwand - TRH - West | Aussenwand Typ VIP - TRH | | | | Grundriss: 1A_21003EG-1_S; Schnitt: 1A_21014SEE_G | |
| 330 | 335 | | | | Kuntzhartzputz | 0,015 | 8,8 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Vakuumsandwichelement VIP/EPS | 0,09 | 8,8 | externes EPD: EPD-POR-20200138-IBC1-DE | | |
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,2 | 1,182 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 8,8 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW Treppenhaus EPS Putz | Aussenwand - TRH - West | Aussenwand Nord - Regelfassade - Treppenhaus West | | | | Grundriss: 1A_21004OG1-1_KSchnitt: 1A_21014SEE_G | |
| 330 | 335 | | | | Kuntzhartzputz | 0,01 | 20,1 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | Wärmedämmung Hart Neu | 0,3 | 20,1 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | | | | | Sockeldämmplatte WDVS | 0,2 | 7,103 | Extrudierter Polystyrol Dammstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putz | 0,01 | 20,1 | Gipsputz (innen) (de) | | |
| 330 | 336 | | | | Anstrich | 0,0025 | 20,1 | Innenfarbe Dispersionsfarbe scheuerfest (de) | | |
| 330 | | Aussenwände | | Aussenwand - TRH - Mitte | Aussenwand TRH - Nord - EPS | | | | Grundriss: 1A_21004OG1-1_K; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G; Broschüre Dämmart | |

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| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge (m2) Menge Neu [m³] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 330 | 335 | | | | Kunstharzputz | 0,015 | 14,4 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | EPS 031 | 0,3 | 14,4 | EPS-Hartschaum (grau, Rohdichte 20 bis 25 kg/m³) | | |
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,2 | 4,955 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Beton | 0,3 | | Transportbeton C25/30 (de); Bewehrungsstahl (de) en de | | Gesamt Stahlbeton Neu Außenwände. Berechnung siehe Tabelle: Übersicht-Flächen_Volumen_Neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 14,4 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW mit Isover | Aussenwand - TRH - Mitte | Aussenwand Typ Isover | | | | Grundriss: 1A_21104OG1-1_0; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G | |
| 330 | 335 | | | | Isover Ultimate | 0,2 | 14,464 | Mineralwolle (Fassaden-Dämmung) | | |
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,2 | 4,824 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 17,366 | Gipsputz (innen) (de) | | |
| 330 | | Aussenwände | AW Treppenhaus MW Putz | Aussenwand - TRH - Mitte | Aussenwand Typ Steinwolle | | | | Grundriss: 1A_21104OG1-1_0; Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021AO_G | |
| 330 | 335 | | | | Kunsthartzputz | 0,015 | 11,1 | Kunstharzputz (de) en de | | |
| 330 | 335 | | | | WDVS Steinwolle | 0,2 | 11,1 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 330 | 335 | | | | Sockeldämmplatte WDVS | 0,2 | 5,148 | Extrudierter Polystyrol Dämmstoff (XPS) | | |
| 330 | 331 | | | | Mauerwerk | 0,3 | | Mauerziegel (ungefüllt) (de) | | Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu |
| 330 | 336 | | | | Putzmörtel | 0,01 | 14,2 | Gipsputz (innen) (de) | | |
| Sonderpositionen | | | | | | | | | | |
| 360 | | Dach | | Attika Ausrichtung Süd | Attika Süd in Volumen Angegeben | | Menge Neu [m³] | | Grundriss: 1A_21004OG1-2_N; Schnitt: AA, HH; Detail Dach 1A_22601_E | |
| 360 | 364 | | | | Sockelputz (Spritzwasserbereich) | 0,015 | 0,448 | Kunstharzputz (de) en de | | |
| 360 | 364 | | | | WDVS | | 1,792 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | OSB Platten | | 3,284 | Spanplatte (generisch) (de | | |
| 360 | 364 | | | | MW-Dämmung | | 5,509 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | EPS 031 | | 2,374 | EPS-Hartschaum (Rohdichte 15 kg/m³) | | |
| 360 | 361 | | | | Kantholz | | 0,313 | Konstruktionsvollholz (Durchschnitt DE) | | |
| 360 | 364 | | | | Alublech | | 0,115 | Aluminiumblech (de) | | |
| 360 | | Dach | | Attika Ausrichtung Nord | Attika Nord in Volumen Angegeben | | Menge Neu [m³] | | Grundriss: 1A_21004OG1-2_N; Schnitt: AA, HH; Detail Dach 1A_22604_B | |
| 360 | 364 | | | | Sockelputz (Spritzwasserbereich) | 0,015 | 0,855 | Kunstharzputz (de) en de | | |
| 360 | 364 | | | | WDVS | | 12,824 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | OSB Platten | | 1,670 | Spanplatte (generisch) (de | | |
| 360 | 364 | | | | MW-Dämmung | | 1,993 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | EPS 031 | | 0,880 | EPS-Hartschaum (Rohdichte 15 kg/m³) | | |
| 360 | 361 | | | | Kantholz | | 0,320 | Konstruktionsvollholz (Durchschnitt DE) | | |
| 360 | 364 | | | | Alublech | | 0,163 | Aluminiumblech (de) | | |
| 360 | | Dach | | Pultfirst Ausrichtung Nord | Pultfirst Nord in Volumen Angegeben | | Menge Neu [m³] | | Grundriss: 1A_21004OG1-2_N; Schnitt: AA, HH; Detail Dach 1A_22602_B | |
| 360 | 364 | | | | Sockelputz (Spritzwasserbereich) | 0,015 | 0,742 | Kunstharzputz (de) en de | | |
| 360 | 364 | | | | WDVS | | 9,738 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | OSB Platten | | 0,371 | Spanplatte (generisch) (de | | |
| 360 | 364 | | | | MW-Dämmung | | 0,884 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | EPS 031 | | 1,113 | EPS-Hartschaum (Rohdichte 15 kg/m³) | | |
| 360 | 364 | | | | Alublech | | 0,080 | Aluminiumblech (de) | | |
| 360 | | Dach | | Attika Anbau Ausrichtung Süd | Attika Süd in Volumen Angegeben | | Menge Neu [m³] | | Grundriss: 1A_21004OG1-2_N; Schnitt: AA, HH; Detail Dach 1A_22601_E | |
| 360 | 364 | | | | Sockelputz (Spritzwasserbereich) | 0,015 | 0,195 | Kunstharzputz (de) en de | | |
| 360 | 364 | | | | WDVS | | 0,780 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | OSB Platten | | 1,430 | Spanplatte (generisch) (de | | |
| 360 | 364 | | | | MW-Dämmung | | 5,066 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | EPS 031 | | 1,207 | EPS-Hartschaum (Rohdichte 15 kg/m³) | | |
| 360 | 361 | | | | Kantholz | | 0,136 | Konstruktionsvollholz (Durchschnitt DE) | | |
| 360 | 364 | | | | Alublech | | 0,050 | Aluminiumblech (de) | | |
| 360 | | Dach | | Attika Anbau Ausrichtung Nord | Attika Nord in Volumen Angegeben | | Menge Neu [m³] | | Grundriss: 1A_21004OG1-2_N; Schnitt: AA, HH; Detail Dach 1A_22604_B | |
| 360 | 364 | | | | Sockelputz (Spritzwasserbereich) | 0,015 | 0,345 | Kunstharzputz (de) en de | | |
| 360 | 364 | | | | WDVS | | 5,173 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | OSB Platten | | 0,674 | Spanplatte (generisch) (de | | |
| 360 | 364 | | | | MW-Dämmung | | 0,804 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | EPS 031 | | 0,355 | EPS-Hartschaum (Rohdichte 15 kg/m³) | | |
| 360 | 361 | | | | Kantholz | | 0,129 | Konstruktionsvollholz (Durchschnitt DE) | | |
| 360 | 364 | | | | Alublech | | 0,066 | Aluminiumblech (de) | | |
| 360 | | Dach | | Pultfirst Anbau Ausrichtung Nord | Pultfirst Nord in Volumen Angegeben | | Menge Neu [m³] | | Grundriss: 1A_21004OG1-2_N; Schnitt: AA, HH; Detail Dach 1A_22602_B | |
| 360 | 364 | | | | Sockelputz (Spritzwasserbereich) | 0,015 | 0,338 | Kunstharzputz (de) en de | | |
| 360 | 364 | | | | WDVS | | 4,440 | Mineralwolle (Fassaden-Dämmung) (de) | | |
| 360 | 364 | | | | OSB Platten | | 0,169 | Spanplatte (generisch) (de | | |
| 360 | 364 | | | | MW-Dämmung | | 0,403 | Mineralwolle (Fassaden-Dämmung) (de) | | |

Bauteilkatalog Uhlandschule

Maximilian Schleicher

| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Bauteilbezeichnung (laut Bauteilkatalog) | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Schichtdicke [m] = m³/m² | Menge [m2] Menge Neu [m²] | eLCA Datenset | Quellen (hier bitte alle verwendeten Dokumente verweisen und bearbeitete Pläne mit Messungen etc. ablegen) | Kommentar / Anmerkung |
|---|---|---|---|---|---|---|---|---|---|---|
| 360 | 364 | | | | EPS 031 | | 0,507 | EPS-Hartschaum (Rohdichte 15 kg/m³) | | |
| 360 | 364 | | | | Alublech | | 0,037 | Aluminiumblech (de) | | |

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| Bauteilgruppe_KG | Bauteil-KG | Bauteilgruppe Name | Detail Dokumenten Name | Zuordnung bzw. Lage | Bauteil-/ Schichtbezeichnung | Hersteller | Produktname | Menge | Breite Fenster | Höhe Fenster | Fläche Gesamt | Name Datensatz in eLCA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fenster EG | | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 169 2.1.12 TH EG Nord | Fenster TPH - Mitte - Nor | Fenster TPH - Mitte - Nord | SCHÜCO | ll mit AWS 90.SI | 1 | 5,21 | 2,535 | 13,21 | Fenster EG TPH - Mitte - Nord - Teil 1 nicht öffenbar; Fenster EG TPH - Mitte - Nord - Teil 2 zum öffnen |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 162 EG Nord Achse C-D 2.1.13-5,161 EG Nord Achse D-E 2.1.13-4, 160 EG Nord Achse E-F 2.1.13-3, 159 EG Nord Achse F-G 2.1.13-2, 158b EG Nord Achse G-H 2.1.13-1 | Fenster Nord Achs C-H | Fenster Nord Klassenzimmer | Schüco | ll mit AWS 90.SI | 1 | 46,95 | 2,46 | 115,50 | Fenster EG Nord Klassenzimmer Teil 1 nicht öffenbar; Fenster EG Nord Klassenzimmer Teil 2 zum öffnen; |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 138 2.1.16 EG TH West | Fenster TPH West | Fenster TPH West | | | 1 | 2,2 | 1,76 | 3,92 | Fenster EG TPH West Teil 1 geschlossen; Fenster EG TPH West Teil 2 zum Öffnen |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 167 Kipp EG Nord WC Achse A-B | Fenster WC West | Fenster WC West | SCHÜCO | AWS/ADS .SI | 2 | 2,67 | 0,888 | 2,37 | Fenster WC West EG & 1.OG |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd | 111 2.1.35 EG Süd textiles Werken | Fenster Süd A-B | Fenster Werken | Schüco | ll mit AWS 90.SI | 1 | 8,64 | 1,887 | 16,30 | Fenster EG 1 Süd Werken Teil 1 nicht zum Öffnen; Fenster EG 1 Süd Werken Teil 2 zum Öffnen; Fenster EG Nord Klassenzimmer Teil 3 Höhere |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd | Kein Detail Vorhanden, Nur Lieferschein | Fenster AW Süd | Oberlichter Süd | | | 1 | 46,69 | 0,85 | 39,69 | Oberlicht Süd EG |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Ost | Nicht Vorhanden | Fenster TPH - Mitte - Ost | Fenster TPH - Mitte - Ost | SCHÜCO | ll mit AWS 90.SI | 1 | 2,3 | 1,88 | 4,32 | Fenster Treppenhaus Mitte Ausrichtung Ost |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord Anbau | 155a EG Nord 2.1.11-1; 156a EG Nord 2.1.11-2; 157a EG Nord 2.1.11-3 | Fenster Nord Achs L-M | Fenster Nord Klassenzimmer | Schüco | ll mit AWS 90.SI | 1 | 26,92 | 1,965 | 52,90 | Fenster EG Anbau Nord Klassenzimmer Teil 1 nicht öffenbar; Fenster EG 1 Süd Werken Teil 2 zum Öffnen [4240803]; Fenster EG Anbau Nord Klassenzimmer Teil 3 Höhere Länge |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Ost Anbau | 158a Ost EG Drehfenster WC | Fenster Ost Fassade Anbau | Fenster Öffenbar Ost | SCHÜCO | ll mit AWS 90.SI | 1 | 1,126 | 1,095 | 1,23 | Fenster EG Drehfenster WC Ost |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd Anbau | Kein Detail Vorhanden, Nur Lieferschein | Fenster AW Süd Anbau | Oberlichter Süd | | | 1 | 27,9 | 0,85 | 23,72 | Oberlicht Süd EG Anbau |
| 340 | 334 | | | | | | | | | | | |
| Fenster 1. OG | | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 132b 2.1.18 1+2OG Fenster Nord | Fenster Gang | Fenster Gang | | | 7 | 1,4 | 1,7 | 2,38 | Fenster Gang Nord (EG-2.OG) |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 138 2.1.17 1.OG TH West | Fenster TPH West | Fenster TPH West | | | 1 | 2,2 | 1,76 | 3,92 | Fenster TRH - Nord - West- Außenteil; Fenster TRH - Nord - West- Mittelteil |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 168 Kipp 1.OG Nord WC Achse A-B | Fenster WC West | Fenster WC West | SCHÜCO | AWS/ADS .SI | 2 | 2,64 | 0,888 | 2,34 | Fenster WC West EG & 1.OG |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - West | 119 Kipp 1.OG west; 049 Kipp west H 48 49; 048 Kipp west V 46 47 | Fenster Klasse 101 Kipp | Fenster Klasse 101 | SCHÜCO | AWS/ADS .SI | 1 | 1,335 | 0,925 | 1,23 | Fenster West Kipp Klassenraum 101 |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd | 109 2.1.36 Hauptgebäude 1.OG | Fenster Klasse101;103-107 | Fenster mit PV | SCHÜCO | ll mit AWS 90.SI | 6 | 8,995 | 2,06 | 18,53 | Fenster OG 1 Süd Fenster Klasse101;103-107 Teil Nicht öffenbar; Fenster OG 1 Süd Fenster Klasse101;103-107 Teil öffenbar |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd | 110 2.1.39 Hauptgebäude Lehrmittel 1.OG | Fenster Lehrmittel 102 | Fenster mit PV | SCHÜCO | ll mit AWS 90.SI | 1 | 4,205 | 2,06 | 8,66 | Fenster OG 1 Süd Fenster Lehrmittel 102 Teil Nicht öffenbar; Fenster OG 1 Süd Fenster Lehrmittel 102 Teil öffenbar |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Ost | Nicht Vorhanden | Fenster TPH - Mitte - Ost | Fenster TPH - Mitte - Ost | SCHÜCO | ll mit AWS 90.SI | 1 | 2,3 | 1,88 | 4,32 | Fenster Treppenhaus Mitte Ausrichtung Ost |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 134 2.1.15 TH mitte | Fenster TPH - Mitte - Nor | Fenster TPH - Mitte - Nord | SCHÜCO | ll mit AWS 90.SI | 1 | 5,21 | 1,75 | 9,12 | Fenster TRH - Nord - Mitte - Außenteil; Fenster TRH - Nord - Mitte - Mittelteil |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord Anbau | 133 2.1.18 1.OG Fenster Nord Anbau Ost | Fenster Gang | Fenster Gang | | | 5 | 1,4 | 1,7 | 2,38 | Fenster Gang Nord (EG-2.OG) |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd Anbau | 104 2.1.40 Nebengebäude Treppenhaus | Fenster Anbau TPH | Fenster mit PV | SCHÜCO | ll mit AWS 90.SI | 1 | 3,95 | 1,742 | 6,88 | Fenster OG 1 Süd Nebengebäude Treppenhaus Teil Nicht öffenbar; Fenster OG 1 Süd Nebengebäude Treppenhaus Teil öffenbar |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd Anbau | 104 2.1.40 Nebengebäude Treppenhaus | Fenster Anbau Lehrer:innenzimmer | Fenster mit PV | SCHÜCO | ll mit AWS 90.SI | 4 | 8,985 | 1,742 | 15,62 | Fenster OG 1 Süd Anbau Lehrer:innenzimmer Teil Nicht öffenbar; Fenster OG 1 Süd Anbau Lehrer:innenzimmer Teil öffenbar |
| 340 | 334 | | | | | | | | | | | |
| Fenster 1.OG Oberlichter Anbau | | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 143a Oberlicht Anbau Nord 2.1.27 | Fenster Nord Oberlicht Anbau | Oberlicht - Lüftungsgerät | SCHÜCO | ll mit AWS 90.SI | 3 | 2,256 | 0,79 | 1,78 | Oberlichter 1.OG Anbau Offen |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | nicht Vorhanden - Grundlage Pläne und Schnitte | Fenster Nord Oberlicht Anbau | Oberlicht Geschlossen | SCHÜCO | ll mit AWS 90.SI | 6 | 3,27 | 0,79 | 2,58 | Oberlichter 1.OG Anbau Geschlossen |
| 340 | 334 | | | | | | | | | | | |
| Fenster 2. OG | | | | | | | | | | | | |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd | 107 2.1.41b 2.OG Musik und EDV | Fenster Musik & EDV | Fenster mit PV | SCHÜCO | ll mit AWS 90.SI | 2 | 8,995 | 1,742 | 15,67 | Fenster OG 2 Süd Vorbereitung Chemie/Physik Physik / Chemie Teil Nicht öffenbar; Fenster OG 2 Süd Vorbereitung Chemie/Physik Physik / |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd | 108 2.1.38 2.OG Nebenraum Musik | Fenster Nebenraum Musik | Fenster mit PV | SCHÜCO | ll mit AWS 90.SI | 1 | 4,205 | 1,742 | 7,33 | Fenster OG 2 Süd Nebenraum Musik Teil öffenbar; Fenster OG 2 Süd Nebnraum Musik Teil Nicht öffenbar |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd | 105 2.1.42 2.OG Vorbereitung Physik | Fenster Vorbereitung Physik | Fenster mit PV | SCHÜCO | ll mit AWS 90.SI | 1 | 8,995 | 1,742 | 15,67 | Fenster OG 2 Süd Vorbereitung Chemie/Physik Physik / Chemie Teil Nicht öffenbar; Fenster OG 2 Süd Vorbereitung Chemie/Physik Physik / ChemieTeil öffenbar |
| 340 | 334 | | | | | | | | | | | |
| 340 | 334 | Fenster - Süd | 100d 2.1.41 2.OG Physik und Chemie | Fenster Chemie/Physik | Fenster mit PV | SCHÜCO | ll mit AWS 90.SI | 2 | 8,995 | 1,742 | 15,67 | Fenster OG 2 Süd Vorbereitung Chemie/Physik Physik / Chemie Teil Nicht öffenbar; Fenster OG 2 Süd Vorbereitung Chemie/Physik Physik / |
| 340 | 334 | | | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 340 | 334 | Fenster - Süd | 106 2.1.43 2.OG Vorbereitung Chemie | Fenster Vorbereitung Chemie | Fenster mit PV | SCHÜCO | II mit AWS 90.SI | 1 | 8,995 | | 1,742 | 15,67 | Fenster OG 2 Süd Vorbereitung Chemie/Physik Physik / Chemie Teil Nicht öffenbar; Fenster OG 2 Süd Vorbereitung Chemie/Physik Physik / ChemieTeil öffenbar |
| 340 | 334 | | | | | | | | | | | | |
| 340 | 334 | Fenster - Ost | Nicht Vorhanden | Fenster TPH - Mitte - Ost | Fenster TPH - Mitte - Ost | SCHÜCO | II mit AWS 90.SI | 1 | 2,3 | | 1,88 | 4,32 | Fenster Treppenhaus Mitte Ausrichtung Ost |
| 340 | 334 | | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 134 2.1.15 TH mitte | Fenster TPH - Mitte - Nor | Fenster TPH - Mitte - Nord | SCHÜCO | II mit AWS 90.SI | 1 | 5,21 | | 1,75 | 9,12 | Fenster TRH - Nord - Mitte - Außenteil; Fenster TRH - Nord - Mitte - Mittelteil |
| 340 | 334 | | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 132b 2.1.18 1+2OG Fenster Nord | Fenster Gang | Fenster Gang | | | 7 | 1,4 | 1,7 | | 2,38 | Fenster Gang Nord (EG-2.OG) |
| 340 | 334 | | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 137 2.1.18 2.OG TH West | Fenster TPH West | Fenster TPH West | | | 1 | 2,2 | | 1,78 | 3,92 | Fenster TRH - Nord - West- Außenteil; Fenster TRH - Nord - West- Mittelteil |
| 340 | 334 | | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 165 Kipp 2.OG Nord WC Achse A-B | Fenster WC | Fenster WC | | | 2 | | | | | Fenster WC West 2.OG |
| 340 | 334 | | | | | | | | | | | | |
| Fenster 2.OG Oberlichter | | | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 145 Oberlicht Hauptbau Nord 2.1.25 | Fenster Nord Oberlicht Anbau | Oberlicht - Lüftungsgerät | SCHÜCO | II mit AWS 90.SI | 5 | 3,238 | | 0,845 | 2,74 | Oberlichter 2.OG Offen |
| 340 | 334 | | | | | | | | | | | | |
| 340 | 334 | Fenster - Nord | 150b Oberlicht Hauptbau Nord 2.1.31f | Fenster Nord Oberlicht Anbau | Oberlicht Geschlossen | SCHÜCO | II mit AWS 90.SI | 14 | 2,869 | | 0,845 | 2,42 | Oberlichter 2.OG Geschlossen |
| 340 | 334 | | | | | | | | | | | | |

# Türliste

Projekt: Uhlandschule
Stand: 04.07.2016 Brandschutz- und Objekttüren

Bauherr: Stadt Stuttgart, Hochbauamt 65-6
Hauptstätter Str.66, 70178 Stuttgart

Ansprechpartner Herr Ulmer matthias.ulmer
oder Frau Laage kira.laage@kbk-architekter
Frau Laage (0711) 210 72-12

Index:

Türtypen

| Geschoß | Ra | Türposition A=Aussen, I=Innen, F=Fassade/Fensterelement | Türblattmaterial H=Holz Oberfläche Schichtstoff, M=Metall-Rahmen+Glas, G=Glas, S=Stahl, Hg=Holz mit Glas, Sg=Stahlgitter KTA=Feuchtraumtür, K=Kunststoffrahmen+Glas | Zargentyp/Material Su=Stahlumfassungsz., Se=Stahleckz., Sb=Stahlblockz., M=Metallrahmen Eb=Edelstahlblockz., Hu=Holzumfassungsz. H=Holzrahmen, Ku=Kunststoffrahmen, Tu=Turnhallenzarge | Türart D=Drehtür, Sch=Schiebetür, T=Teleskoptür F=Falttür, R=Rolltor, S=Sektionaltor, H=Hubtor, Asch=Automatische Schiebetür | Zusatzeigenschaften N=nassraumgeeignet, F=feuchtraumgeeignet | Türflügelanzahl/Anschlag DIN rechts/links | Rohbaurichtmaß Breite/Höhe (cm) OK RFB-UK Sturz | Zargenoberfläche | Türaufschlagrichtung i=Innen, a=Außen | Bodenaufbau, Innen (cm) | Bodenaufbau, Außen (cm) | Bodeneinstand | Schallschutz RwR (eingebauter Zusta | Drückergarnitur innen D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Drückergarnitur außen D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Türoberflächen | Klemmschutz ganze Höhe: BS = Bandseite BGS = Bandgegenseite | Datensatz in eLCA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Titel 1** | | | | | | | | | | | | | | | | | | | |
| EG | 073 WC Schüler | I_ | H_stumpf | Su Sp40*55 | D | F | Re | 88,5*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| EG | 074 Putzraum | I_ | H_stumpf | Su Sp40*55 | D | F | Li | 101*213 | RAL 9016 | a | ±0 | ±0 | 0 | 0 | Dr | Kn B | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 072 Vorraum WC | I_ | H_stumpf | Su Sp40*55 | D | F | Li | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 071 Vorraum WC Schülerinnen | I_ | H_stumpf | Su Sp40*55 | D | F | Re | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 070 WC Schülerinnen | I_ | H_stumpf | Su Sp40*55 | D | F | Li | 88,5*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| EG | 081 Flur | I_ | H_stumpf | Se Sp40*55 | D | | Re | 101*213 | NCS S8000N | a | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 001.1 Textiles Werken | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Kn B | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 002 Hausmeisterraum | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr 2 | Dr 2 | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 083 Flur | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | NCS S8000N | a | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |

Türtypen

| Geschoß | Ra | Türposition<br>A=Aussen, I=Innen, F=Fassade/Fensterelement | Türblattmaterial<br>H=Holz Oberfläche Schichtstoff M=Metall-Rahmen+Glas, G=Glas, S=Stahl, Hg=Holz mit Glas, Sg=Stahlglas KTA= Feuchtraumtür, K=Kunststoffrahmen+Glas | Zargentyp/Material<br>Su=Stahlumfassungsz., Se=Stahleckz., Sb=Stahlblockz., M=Metallrahmen, Eb=Edelstahlblockz., Hu=Holzumfassungsz., H=Holzrahmen, Ku=Kunststoffrahmen, Tu=Turnhallenzarge | Türart<br>D=Drehtür, Sch=Schiebetür, T=Teleskoptür, F=Falttür, R=Rolltor, S=Sektionaltor, H=Hubtor, Asch=Automatische Schiebetür | Zusatzeigenschaften<br>N=nassraumgeeignet, F=feuchtraumgeeignet | Türflügelanzahl/Anschlag<br>DIN rechts/links | Rohbaurichtmaß Breite/Höhe (cm)<br>OKRFB-UK Sturz | Zargenoberfläche | Türaufschlagrichtung<br>i=Innen, a=Außen | Bodenaufbau, Innen (cm) | Bodenaufbau, Außen (cm) | Bodeneinstand | Schallschutz RwR (eingebauter Zusta | Drückergarnitur innen<br>D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Drückergarnitur außen<br>D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Türoberflächen | Klemmschutz ganze Höhe:<br>BS = Bandseite<br>BGS = Bandgegenseite | Datensatz in eLCA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EG | 003 NR Textiles Werken | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 004.1 Bildende Kunst | I_ | H_stumpf | Su Sp40*55 | D | | Re | 101*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Kn B | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 004.2 Bildende Kunst | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Kn B | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 005 Nebenraum Bildende Kunst | I_ | H_stumpf | Su Sp40*55 | D | | Re | 101*213 | NCS S8000N | i | ±0 | ±0 | 0 | | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 006.1 Nebenraum Brennraum | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*208 | NCS S8000N | a | ±0 | ±0 | 0 | | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 006.2 Nebenraum Brennraum | I_ | H_stumpf | Su Sp40*55 | D | | Re | 101*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 007.1 M.fkt. Fachunterricht | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Kn B | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 007.2 M.fkt. Fachunterricht | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 008.1 Lehrküche/Theorie | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*205 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |

Türtypen

| Geschoß | Ra | Türposition A=Aussen, I=Innen, F=Fassade/Fensterelement | Türblattmaterial H=Holz Oberfläche Schichtstoff, M=Metall-Rahmen-Glas, G=Glas, S=Stahl, Hg=Holz mit Glas, Sg=Stahl mit Glas KTA= Feuchtraumtür, K=Kunststoffrahmen+Glas | Zargentyp/Material Su=Stahlumfassungsz., Se=Stahleckz., Sb=Stahlblockz., M=Metallrahmen, Eb=Edelstahlblockz., Hu=Holzumfassungsz., H=Holzrahmen, Ku=Kunststoffrahmen, Tu=Turnhallenzarge | Türart D=Drehtür, Sch=Schiebetür, T=Teleskoptür, F=Falttür, R=Rolltor, S=Sektionaltor, H=Hubtor, Asch=Automatische Schiebetür | Zusatzeigenschaften N=nassraumgeeignet, F=feuchtraumgeeignet | Türflügelanzahl/Anschlag DIN rechts/links | Rohbaurichtmaß Breite/Höhe (cm) OK RFB-UK Sturz | Zargenoberfläche | Türaufschlagrichtung i=Innen, a=Außen | Bodenaufbau, Innen (cm) | Bodenaufbau, Außen (cm) | Bodeneinstand | Schallschutz RwR (eingebauter Zustan | Drückergarnitur innen D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Drückergarnitur außen D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Türoberflächen | Klemmschutz ganze Höhe: BS = Bandseite BGS = Bandgegenseite | Datensatz in eLCA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EG | 009 Nebenraum Lehrküche | I_ | H_stumpf | Su Sp40*55 | D | | Re | 113,5*206 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| EG | 010.1 Technik/Werken | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*205 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| EG | 010.2 Technik/Werken | I_ | H_stumpf | Su Sp40*55 | D | | Re | 101*213 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 011 Maschinenraum | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| EG | 012.1 Technik/Werken | I_ | H_stumpf | Su Sp40*55 | D | | Re | 113*205 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| EG | 076 WC Lehrer | I_ | H_stumpf | Su Sp40*55 | D | F | Re | 88,5*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| EG | 075 Vorraum WC Lehrer | I_ | H_stumpf | Su Sp40*55 | D | F | Li | 88,5*205 | NCS S8000N | a | ±0 | ±0 | 0 | 0 | Dr | Kn B | Resopal 10622-60 | | Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| EG | 078 Vorraum WC Lehrerinnen | I_ | H_stumpf | Su Sp40*55 | D | F | Re | 88,5*205 | NCS S8000N | a | ±0 | ±0 | 0 | 0 | Dr | Kn B | Resopal 10622-60 | | Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| EG | 077 WC Lehrerinnen | I_ | H_stumpf | Su Sp40*55 | D | F | Re | 88,5*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |

Türtypen

| Geschoß | Ra | Türposition A=Aussen, I=Innen, F=Fassade/Fensterelement | Türblattmaterial H=Holz Oberfläche Schichtstoff M=Metall-Rahmen+Glas, G=Glas, S=Stahl, Hg=Holz mit Glas, Sg=Stahlgitter KTA=Feuchtraumtür, K=Kunststoffrahmen+Glas | Zargentyp/Material Su=Stahlumfassungsz., Se=Stahleckz., Sb=Stahlblockz., M=Metallrahmen, Eb=Edelstahlblockz., Hu=Holzumfassungsz., H=Holzrahmen, Ku=Kunststoffrahmen, Tu=Turnhallenzarge | Türart D=Drehtür, Sch=Schiebetür, T=Teleskoptür, F=Falttür, R=Rolltor, S=Sektionaltor, H=Hubtor, Asch=Automatische Schiebetür | Zusatzeigenschaften N=nassraumgeeignet, F=feuchtraumgeeignet | Türflügelanzahl/Anschlag DIN rechts/links | Rohbaurichtmaß Breite/Höhe (cm) OKRFB-UK Sturz | Zargenoberfläche | Türaufschlagrichtung i=Innen, a=Außen | Bodenaufbau, Innen (cm) | Bodenaufbau, Außen (cm) | Bodeneinstand | Schallschutz RwR (eingebauter Zusta | Drückergarnitur innen D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Drückergarnitur außen D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Türoberflächen | Klemmschutz ganze Höhe: BS = Bandseite BGS = Bandgegenseite | Datensatz in eLCA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EG | 079 Putzraum | I_ | H_stumpf | Su Sp40*55 | D | F | Li | 88,5*170 | NCS S8000N | a | ±0 | ±0 | 0 | 0 | Dr | Kn B | Resopal 10622-60 | | Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 173 WC Lehrer | I_ | H_stumpf | Su Sp40*55 | D | F | Re | 88,5*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 174 WC Lehrerinnen | I_ | H_stumpf | Su Sp40*55 | D | F | Li | 101*213 | RAL 9016 | a | ±0 | ±0 | 0 | 0 | Dr | Kn B | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 1.OG | 172 Vorraum WC Lehrer | I_ | H_stumpf | Su Sp40*55 | D | F | Li | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Kn B | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 1.OG | 171 WC Behinderten | I_ | H_stumpf | Su Sp40*55 | D | F | Li | 101*213 | RAL 9016 | a | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 1.OG | 170 Putzraum | I_ | H_stumpf | Su Sp40*55 | D | F | Li | 101*213 | RAL 9016 | a | ±0 | ±0 | 0 | 0 | Dr | Kn B | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 1.OG | 181 Flur | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*213 | NCS S8000N | a | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 101.1 Klasse | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*213 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr 2 | Dr 2 | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 101.2 Klasse | I_ | H_stumpf | Su Sp40*55 | D | | Re | 113,5*213 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |

Türtypen

| Geschoß | Ra[um] | Türposition<br>A=Aussen, I=Innen, F=Fassade/Fensterelement | Türblattmaterial<br>H=Holz Oberfläche Schichtstoff M=Metall-Rahmen+Glas, G=Glas, S=Stahl, Hg=Holz mit Glas, Sg=Stahlglas KTA= Feuchtraumtür, K=Kunststoffrahmen+Glas | Zargentyp/Material<br>Su=Stahlumfassungsz., Se=Stahleckz., Sb=Stahlblockz., M=Metallrahmen, Eb=Edelstahlblockz., Hu=Holzumfassungsz., H=Holzrahmen, Ku=Kunststoffrahmen, Tu=Turnhallenzarge | Türart<br>D=Drehtür, Sch=Schiebetür, T=Teleskoptür, F=Falttür, R=Rolltor, S=Sektionaltor, H=Hubtor, Asch=Automatische Schiebetür | Zusatzeigenschaften<br>N=nassraumgeeignet, F=feuchtraumgeeignet | Türflügelanzahl/Anschlag<br>DIN rechts/links | Rohbaurichtmaß Breite/Höhe (cm)<br>OK RFB-UK Sturz | Zargenoberfläche | Türaufschlagrichtung<br>i=Innen, a=Außen | Bodenaufbau, Innen (cm) | Bodenaufbau, Außen (cm) | Bodeneinstand | Schallschutz RwR (eingebauter Zusta | Drückergarnitur innen<br>D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Drückergarnitur außen<br>D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Türoberflächen | Klemmschutz ganze Höhe:<br>BS = Bandseite<br>BGS = Bandgegenseite | Datensatz in eLCA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.OG | 102.1 Lehrmittel | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Kn B | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 102.2 Lehrmittel | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 103 Klasse | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*205 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr 2 | Dr 2 | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 104 Klasse | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*205 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr 2 | Dr 2 | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 105 Klasse | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*205 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr 2 | Dr 2 | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 106 Klasse | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*205 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr 2 | Dr 2 | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 107 Klasse | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*205 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr 2 | Dr 2 | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 108.1 Lehrerzimmer | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*205 | RAL 9016 | i | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 9417-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 1.OG | 108.2 Lehrerzimmer | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |

Türtypen

| Geschoß | Ra | Türposition A=Aussen, I=Innen, F=Fassade/Fensterelement | Türblattmaterial H=Holz Oberfläche Schichtstoff M=Metall-Rahmen+Glas, G=Glas, S=Stahl, Hg=Holz mit Glas, Sg=Stahl gitter KTA= Feuchtraumtür, K=Kunststoffrahmen+Glas | Zargentyp/Material Su=Stahlumfassungsz., Se=Stahleckz., Sb=Stahlblockz., M=Metallrahmen Eb=Edelstahlblockz., Hu=Holzumfassungsz. H=Holzrahmen, Ku=Kunststoffrahmen, Tu=Turnhallenzarge | Türart D=Drehtür, Sch=Schiebetür, T=Teleskoptür F=Falttür, R=Rolltor, S=Sektionaltor, H=Hubtor, Asch=Automatische Schiebetür | Zusatzeigenschaften N=nassraumgeeignet, F=feuchtraumgeeignet | Türflügelanzahl/Anschlag DIN rechts/links | Rohbaurichtmaß Breite/Höhe (cm) OK RFB-UK Sturz | Zargenoberfläche | Türaufschlagrichtung i=Innen, a=Außen | Bodenaufbau, Innen (cm) | Bodenaufbau, Außen (cm) | Bodeneinstand | Schallschutz RwR (eingebauter Zusta | Drückergarnitur innen D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Drückergarnitur außen D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Türoberflächen | Klemmschutz ganze Höhe: BS = Bandseite BGS = Bandgegenseite | Datensatz in eLCA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.OG | 109.1 Besprechung Sanitätsraum | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 1.OG | 110.1 Stellvertreter | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 1.OG | 110.2 Stellvertreter / Sekretariat | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 1.OG | 111.1 Sekretariat | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 32 | Dr 2 | Dr 2 | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 1.OG | 111.2 Sekretariat / Schulleiter | I_ | H_stumpf | Su Sp40*55 | D | | Re | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 1.OG | 113 Lehrerzimmer | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*205 | RAL 9016 | a | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 2.OG | 273 WC Schüler | I_ | H_stumpf | Su Sp40*55 | D | | Re | 88,5*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 2.OG | 274 Putzraum | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | RAL 9016 | a | ±0 | ±0 | 0 | 0 | Dr | Kn B | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 2.OG | 272 Vorraum WC | I_ | H_stumpf | Su Sp40*55 | D | | Li | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |

Türtypen

| Geschoß | Ra | Türposition<br>A=Aussen, I=Innen, F=Fassade/Fensterelement | Türblattmaterial<br>H=Holz Oberfläche Schichtstoff M=Metall-Rahmen+Glas, G=Glas, S=Stahl, Hg=Holz mit Glas, Sg=Stahlgitter KTA= Feuchtraumtür, K=Kunststoffrahmen+Glas | Zargentyp/Material<br>Su=Stahlumfassungsz., Se=Stahleckz., Sb=Stahlblockz., Mr=Metallrahmen, Eb=Edelstahlblockz., Hu=Holzumfassungsz., H=Holzrahmen, Ku=Kunststoffrahmen, Tu=Turnhallenzarge | Türart<br>D=Drehtür, Sch=Schiebetür, T=Teleskoptür, F=Falttür, R=Rolltor, S=Sektionaltor, H=Hubtor, Asch=Automatische Schiebetür | Zusatzeigenschaften<br>N=nassraumgeeignet, F=feuchtraumgeeignet | Türflügelanzahl/Anschlag<br>DIN rechts/links | Rohbaurichtmaß Breite/Höhe (cm)<br>OK RFB-UK Sturz | Zargenoberfläche | Türaufschlagrichtung<br>i=Innen, a=Außen | Bodenaufbau, Innen (cm) | Bodenaufbau, Außen (cm) | Bodeneinstand | Schallschutz RwR (eingebauter Zustar | Drückergarnitur innen<br>D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bogelgriff | Drückergarnitur außen<br>D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bogelgriff | Türoberflächen | Klemmschutz ganze Höhe:<br>BS = Bandseite<br>BGS = Bandgegenseite | Datensatz in eLCA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.OG | 271 Vorraum WC | I_ | H_stumpf | Su Sp40*55 | D | | Re | 101*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 2.OG | 270 WC Schülerinnen | I_ | H_stumpf | Su Sp40*55 | D | | Li | 88,5*213 | RAL 9016 | i | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 9417-60 | | Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 2.OG | 281 Flur | I_ | H_stumpf | Su Sp40*55 | D | | Re | 101*213 | NCS S8000N | a | ±0 | ±0 | 0 | 0 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 2.OG | 201.1 Musikraum | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 2.OG | 201.2 Musikraum | I_ | H_stumpf | Su Sp40*55 | D | | Re | 113,5*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 2.OG | 202.1 Nebenraum Musik | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Kn B | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 2.OG | 202.2 Nebenraum Musik | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*213 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 2.OG | 203.1 Vorbereitung Physik | I_ | H_stumpf | Su Sp40*55 | D | | Re | 113,5*205 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 2.OG | 203.2 Vorbereitung Physik | I_ | H_stumpf | Su Sp40*55 | D | | Re | 101*213 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |

Türtypen

| Geschoß | Ra | Türposition A=Aussen, I=Innen, F=Fassade/Fensterelement | Türblattmaterial H=Holz Oberfläche Schichtstoff, M=Metall-Rahmen+Glas, G=Glas, S=Stahl, Hg=Holz mit Glas, Sg=Stahlglas KTA=Feuchtraumtür, K=Kunststoffrahmen+Glas | Zargentyp/Material Su=Stahlumfassungsz., Se=Stahleckz., Sb=Stahlblockz., M=Metallrahmen, Eb=Edelstahlblockz., Hu=Holzumfassungsz., H=Holzrahmen, Ku=Kunststoffrahmen, Tu=Turnhallenzarge | Türart D=Drehtür, Sch=Schiebetür, T=Teleskoptür, F=Falttür, R=Rolltor, S=Sektionaltor, H=Hubtor, Asch=Automatische Schiebetür | Zusatzeigenschaften N=nassraumgeeignet, F=feuchtraumgeeignet | Türflügelanzahl/Anschlag DIN rechts/links | Rohbaurichtmaß Breite/Höhe (cm) OK RFB-UK Sturz | Zargenoberfläche | Türaufschlagrichtung i=Innen, a=Außen | Bodenaufbau, Innen (cm) | Bodenaufbau, Außen (cm) | Bodeneinstand | Schallschutz RwR (eingebauter Zusta | Drückergarnitur innen D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Drückergarnitur außen D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Türoberflächen | Klemmschutz ganze Höhe: BS = Bandseite BGS = Bandgegenseite | Datensatz in eLCA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.OG | 204 Physik | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*205 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 2.OG | 205.1 Vorbereitung Chemie | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*203 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 2.OG | 205.2 Vorbereitung Chemie | I_ | H_stumpf | Su Sp40*55 | D | | Re | 101*213 | NCS S8000N | i | ±0 | ±0 | 0 | | Dr | Dr | Resopal 10622-60 | | Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch)) |
| 2.OG | 206 Chemie | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*205 | NCS S8000N | a | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |
| 2.OG | 207 EDV | I_ | H_stumpf | Su Sp40*55 | D | | Li | 113,5*201 | NCS S8000N | i | ±0 | ±0 | 0 | 32 | Dr | Kn A | Resopal 10622-60 | | Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de)) |

hutztüren Gänge

| Geschoss | Tür Nummer | Quelle / Detail | Abmessungen | Material Rahmen | Rahmendicke Blendrahmen | Rahmendicke Flügel | Material Innen | Anzahl | Name in eLCA | Kommentar |
|---|---|---|---|---|---|---|---|---|---|---|
| OG 1 | 180, 183, 186.1 | 1A_22532_A | 2,74*2,37 | Aluminium | 17 | 9 | Glas | 3 | Brandschutztür 1.OG | In eLCA mit dem Fenster Assistent erstellt |

Türtypen

| Geschoß | Ra | Türposition<br>A=Aussen, I=Innen, F=Fassade/Fensterelement | Türblattmaterial<br>H=Holz Oberfläche Schichtstoff, M=Metall-Rahmen+Glas, G=Glas, S=Stahl, Hg=Holz mit Glas, Sg=Stahlgitter KTA=Feuchtraumtür, K=Kunststoffrahmen+Glas | Zargentyp/Material<br>Su=Stahlumfassungsz., Se=Stahleckz., Sb=Stahlblockz., M=Metallrahmen, Eb=Edelstahlblockz., Hu=Holzumfassungsz., H=Holzrahmen, Ku=Kunststoffrahmen, Tu=Turnhallenzarge | Türart<br>D=Drehtür, Sch=Schiebetür, T=Teleskoptür, F=Falttür, R=Rolltor, S=Sektionaltor, H=Hubtor, Asch=Automatische Schiebetür | Zusatzeigenschaften<br>N=nassraumgeeignet, F=feuchtraumgeeignet | Türflügelanzahl/Anschlag<br>DIN rechts/links | Rohbaurichtmaß Breite/Höhe (cm)<br>OK RFB-UK Sturz | Zargenoberfläche | Türaufschlagrichtung<br>i=Innen, a=Außen | Bodenaufbau, Innen (cm) | Bodenaufbau, Außen (cm) | Bodeneinstand | Schallschutz RwR (eingebauter Zustar | Drückergarnitur innen<br>D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Drückergarnitur außen<br>D=Drücker, K=Knauf, S=Stoßstange, H=Hebel, M=Muschel, Bg=Bügelgriff | Türoberflächen | Klemmschutz ganze Höhe:<br>BS = Bandseite<br>BGS = Bandgegenseite | Datensatz in eLCA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OG1 Anbau | 186.2, 18‹ 1A_22531_A | 2,74*2,16 | Aluminium | 17 | 9 | Glas | 3 | Brandschutztür Gang 1.OG Anbau & 2.OG | In eLCA mit dem Fenster Assistent erstellt | | | | | | | | | | |
| OG2 | 80,283,28 1A_22530_A | 2,74*2,16 | Aluminium | 17 | 9 | Glas | 3 | Brandschutztür Gang 1.OG Anbau & 2.OG | In eLCA mit dem Fenster Assistent erstellt | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |

| Bauteil | Datensatz eLCA | Component Group | Declared Unit | Menge | Quellen |
|---|---|---|---|---|---|
| Wärmepumpe | Rohre für Stromwärmepumpe (Sole-Wasser, Erdsonde) 7 | 421 | piece | 2 | 2 Wärmepumpen mit a 64 kW Leistung |
| | Stromwärmepumpe (Sole-Wasser, Erdsonde) 70 kW | 421 | piece | 2 | 2 Wärmepumpen mit a 64 kW Leistung |
| Pufferspeicher | Pufferspeicher (Edelstahl) | 421 | kg | 144 | 23 040 1 H04_L-Schema MSR-Wärme- u. Kälteversorgung_Hauptgebäude_Rev |
| Lüftungsanlage | Lüfter dezentral mit WRG (Wand & Decke) 60 m³/h | 431 | piece | 33 | Summe aus Zonen mit Lüftung; Dokumente: Zoning and Energy Simulation IBF |
| PV | Photovoltaiksystem 1000 kWh/m²*a (ohne Stromgutschr | 442 | m² | 672 | Detail PV: 1A_21304LP4_B |
| Fahrstuhl | Fahrstuhl - Grundkomponenten (stockwerkunabhängig) | 461 | piece | 1 | |
| | Fahrstuhl - Komponenten (stockwerkabhängig) | 461 | piece | 3 | 3 Stockwerke (EG-2.OG) |
| | | | | | |
| Sockelbetrag | QNG Datensatz | 410, 420, 430 | kg CO2 Äqui./ | 2761,14 | QNG Leitfaden |

**Appendix B: Front page of the EPD used for the vacuum insulation material.**

## UMWELT-PRODUKTDEKLARATION

nach *ISO 14025* und *EN 15804+A1*

| | |
|---|---|
| Deklarationsinhaber | **Porextherm Dämmstoffe GmbH** |
| Herausgeber | Institut Bauen und Umwelt e.V. (IBU) |
| Programmhalter | Institut Bauen und Umwelt e.V. (IBU) |
| Deklarationsnummer | EPD-POR-20200138-IBC1-DE |
| Ausstellungsdatum | 25.08.2020 |
| Gültig bis | 24.08.2025 |

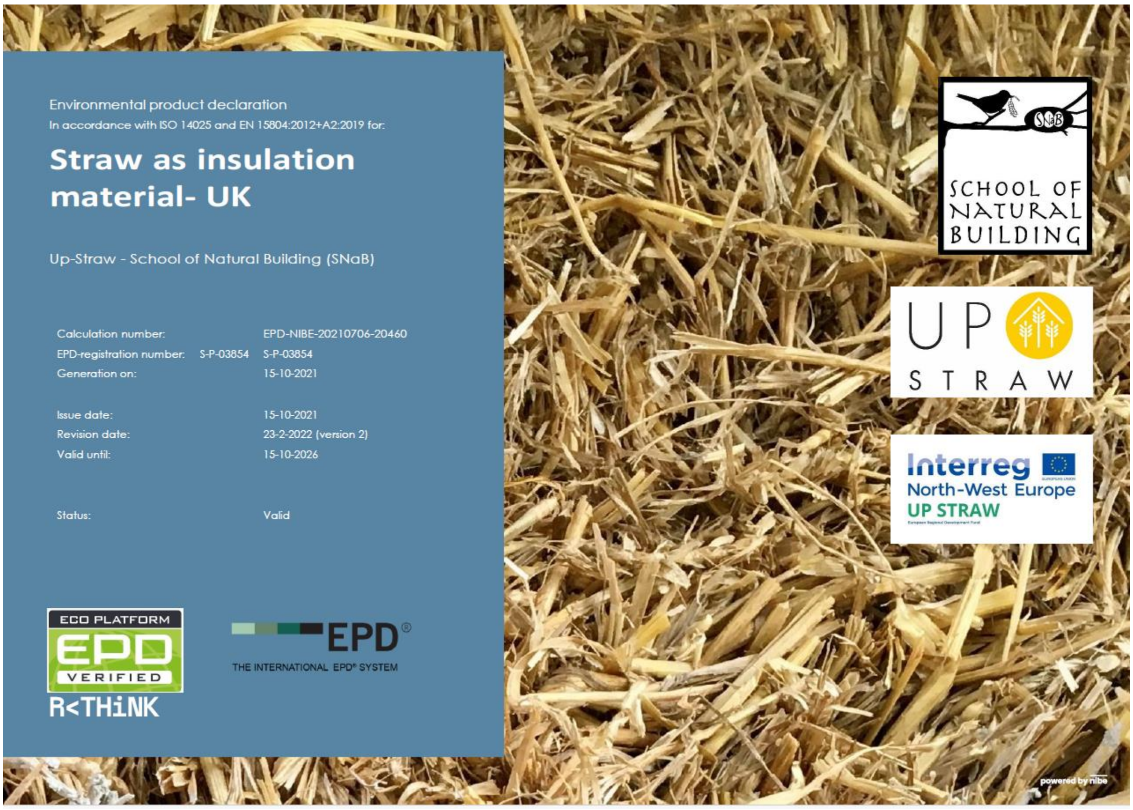
**Vakuum-Isolations-Paneele**
Vacupor® NT-B2-S / Vacuspeed®
und
Vacupor® XPS-B2-S / Vacuspeed® XPS
Vacupor® RP-B2-S / Vacuspeed® RP
Vacupor® TS-B2-S / Vacuspeed® TS

**Porextherm Dämmstoffe GmbH**

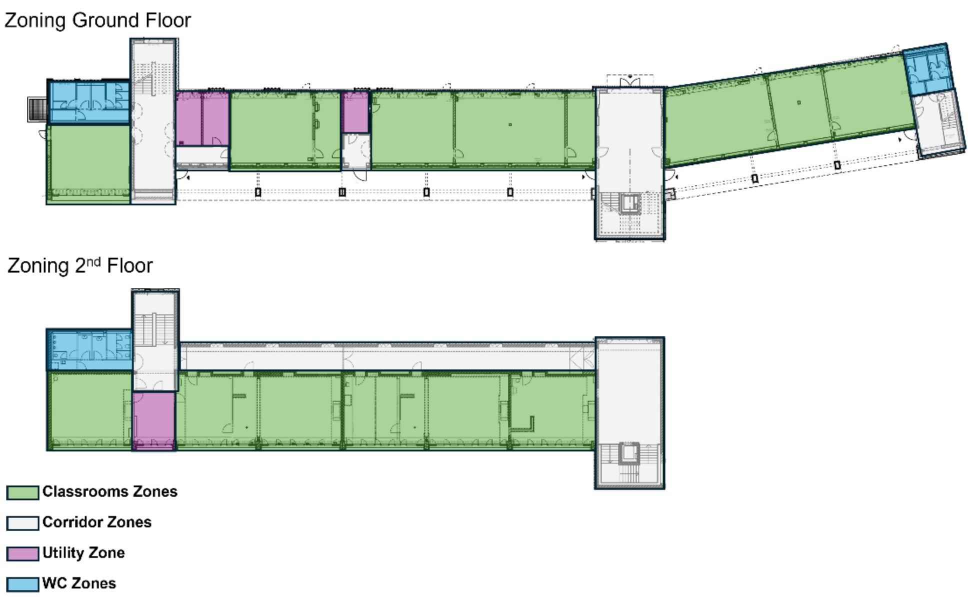
Institut Bauen und Umwelt e.V.

**www.ibu-epd.com | https://epd-online.com**

**Appendix C: Front page of the used EPD for the straw insulation material.**




**Appendix D: Zoning of the energy simulation of the remaining floors.**



**Appendix E: Schedule of the Zones: WC, Corridors, and Utility Rooms**

| Hours of the day | Occupancy WC Fractional | | | Lighting WC fractional | | | Heating WC class-rooms temp. | | | Ventilation WC winter & summer fractional | | | Service Hot Water fractional | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W | WE | H | W | WE | H | W | WE | H | W | WE | H | W | WE | H |
| 0 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 1 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 2 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 3 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 4 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 5 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 6 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0.5 | | | 0 | | |
| 7 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 8 | | | | 0.2 | 0 | 0 | 15 | 15 | 12 | 0.5 | | | 0.5 | | |
| 9 | | | | 0.2 | 0 | 0 | 15 | 15 | 12 | 0.5 | | | 1.0 | | |
| 10 | | | | 0.2 | 0 | 0 | 15 | 15 | 12 | 0.5 | | | 1.0 | | |
| 11 | | 0 | | 0.1 | 0 | 0 | 15 | 15 | 12 | 0.5 | 0 | | 1.0 | 0 | |
| 12 | | | | 0.1 | 0 | 0 | 15 | 15 | 12 | 0.5 | | | 1.0 | | |
| 13 | | | | 0.1 | 0 | 0 | 15 | 15 | 12 | 0.5 | | | 1.0 | | |
| 14 | | | | 0.1 | 0 | 0 | 15 | 15 | 12 | 0.3 | | | 1.0 | | |
| 15 | | | | 0.1 | 0 | 0 | 15 | 15 | 12 | 0.3 | | | 0.5 | | |
| 16 | | | | 0.1 | 0 | 0 | 15 | 15 | 12 | 0.3 | | | 0.5 | | |
| 17 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0.3 | | | 0.3 | | |
| 18 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0.3 | | | 0 | | |
| 19 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 20 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 21 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 22 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |
| 23 | | | | 0 | 0 | 0 | 15 | 15 | 12 | 0 | | | 0 | | |

| Hours of the day | Occupancy Corridors Fractional | | | Lighting Corridors fractional | | | Heating Corridors class-rooms temp. | | |
|---|---|---|---|---|---|---|---|---|---|
| | W | WE | H | W | WE | H | W | WE | H |
| 0 | | | | 0 | 0 | 0 | 15 | 15 | 12 |
| 1 | | | | 0 | 0 | 0 | 15 | 15 | 12 |
| 2 | | 0 | | 0 | 0 | 0 | 15 | 15 | 12 |
| 3 | | | | 0 | 0 | 0 | 15 | 15 | 12 |
| 4 | | | | 0 | 0 | 0 | 15 | 15 | 12 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | | 0 | 0 | 0 | 15 | 15 | 12 |
| 6 | | 0 | 0 | 0 | 15 | 15 | 12 |
| 7 | | 0 | 0 | 0 | 15 | 15 | 12 |
| 8 | | 0.2 | 0 | 0 | 15 | 15 | 12 |
| 9 | | 0.2 | 0 | 0 | 15 | 15 | 12 |
| 10 | | 0.2 | 0 | 0 | 15 | 15 | 12 |
| 11 | | 0.1 | 0 | 0 | 15 | 15 | 12 |
| 12 | | 0.1 | 0 | 0 | 15 | 15 | 12 |
| 13 | | 0.1 | 0 | 0 | 15 | 15 | 12 |
| 14 | | 0.1 | 0 | 0 | 15 | 15 | 12 |
| 15 | | 0.1 | 0 | 0 | 15 | 15 | 12 |
| 16 | | 0.1 | 0 | 0 | 15 | 15 | 12 |
| 17 | | 0 | 0 | 0 | 15 | 15 | 12 |
| 18 | | 0 | 0 | 0 | 15 | 15 | 12 |
| 19 | | 0 | 0 | 0 | 15 | 15 | 12 |
| 20 | | 0 | 0 | 0 | 15 | 15 | 12 |
| 21 | | 0 | 0 | 0 | 15 | 15 | 12 |
| 22 | | 0 | 0 | 0 | 15 | 15 | 12 |
| 23 | | 0 | 0 | 0 | 15 | 15 | 12 |

| **Hours of the day** | **Occupancy Utility Rooms Fractional** | | | **Lighting Utility Rooms fractional** | | | **Heating Utility Rooms temp.** | | | **Cooling Utility Rooms temp.** | | | **Ventilation Utility Rooms winter fractional** | | | **Ventilation Utility Rooms summer fractional** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W | WE | H | W | WE | H | W | WE | H | W | WE | H | W | WE | H | W | WE | H |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | 26 | | 0 | 0 | | | 0 | |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | | | 0 | | | | | |
| 8 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 9 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 10 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 11 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |
| 12 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | | | 1 | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 1 | 0 | 0 | 1 | 0 | 0 | 19 | 17 | 15 | | 1 | | |
| 14 | 1 | 0 | 0 | 0.5 | 0 | 0 | 19 | 17 | 15 | | 1 | | |
| 15 | 1 | 0 | 0 | 0.5 | 0 | 0 | 19 | 17 | 15 | | 1 | | |
| 16 | 1 | 0 | 0 | 0.5 | 0 | 0 | 17 | 17 | 15 | | 1 | | |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | 1 | | |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | 1 | | |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | 1 | | |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | 1 | | |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | 1 | | |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | 1 | | |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 15 | | 1 | | |

**Appendix F: List of school holidays from 2024 in the federal state of Baden-Wüttemberg**

| | | |
|---|---|---|
| 0. 1 Jan | 31. 29 May | 62. 22 Aug |
| 1. 2 Jan | 32. 30 May | 63. 23 Aug |
| 2. 3 Jan | 33. 31 May | 64. 24 Aug |
| 3. 4 Jan | 34. 25 Jul | 65. 25 Aug |
| 4. 5 Jan | 35. 26 Jul | 66. 26 Aug |
| 5. 6 Jan | 36. 27 Jul | 67. 27 Aug |
| 6. 23 Mar | 37. 28 Jul | 68. 28 Aug |
| 7. 24 Mar | 38. 29 Jul | 69. 29 Aug |
| 8. 25 Mar | 39. 30 Jul | 70. 30 Aug |
| 9. 26 Mar | 40. 31 Jul | 71. 31 Aug |
| 10. 27 Mar | 41. 1 Aug | 72. 1 Sep |
| 11. 28 Mar | 42. 2 Aug | 73. 2 Sep |
| 12. 29 Mar | 43. 3 Aug | 74. 3 Sep |
| 13. 30 Mar | 44. 4 Aug | 75. 4 Sep |
| 14. 31 Mar | 45. 5 Aug | 76. 5 Sep |
| 15. 1 Apr | 46. 6 Aug | 77. 6 Sep |
| 16. 2 Apr | 47. 7 Aug | 78. 3 Oct |
| 17. 3 Apr | 48. 8 Aug | 79. 28 Oct |
| 18. 4 Apr | 49. 9 Aug | 80. 29 Oct |
| 19. 5 Apr | 50. 10 Aug | 81. 30 Oct |
| 20. 1 May | 51. 11 Aug | 82. 31 Oct |
| 21. 9 May | 52. 12 Aug | 83. 1 Nov |
| 22. 20 May | 53. 13 Aug | 84. 24 Dec |
| 23. 21 May | 54. 14 Aug | 85. 25 Dec |
| 24. 22 May | 55. 15 Aug | 86. 26 Dec |
| 25. 23 May | 56. 16 Aug | 87. 27 Dec |
| 26. 24 May | 57. 17 Aug | 88. 28 Dec |
| 27. 25 May | 58. 18 Aug | 89. 29 Dec |
| 28. 26 May | 59. 19 Aug | 90. 30 Dec |

| | | |
|---|---|---|
| 29. 27 May | 60. 20 Aug | 91. 31 Dec |
| 30. 28 May | 61. 21 Aug | |

**Appendix G: Technical data sheet of the used PV modules in the PV simulation.**

## Bosch Solar Module c-Si M 60 | EU30117 I EU30123

| Länge [x] | Breite [y] | Rahmenhöhe [z] | Gewicht | Anschlussdose | Steckverbindertyp | Kabel [l] | Frontglasoberfläche |
|---|---|---|---|---|---|---|---|
| 1660,0 | 990,0 | 50,0 | 21 | Spelsberg | MC4 | –800 +1200 | strukturiert |
| x, y, l in mm, ±2; z in mm, ±0,3; Gewicht in kg ±0,5 | | | | | | | |

| Kristallines Solarmodul | |
|---|---|
| Leistungsklassen | 235 Wp, 240 Wp, 245 Wp, 250 Wp |
| Leistungssortierung | –0/+4,99 Wp |
| Aufbau | **Glas-Folie-Laminat**<br>► Eloxierter Aluminiumrahmen<br>► Anschlussdose (IP 65) mit 3 Bypass-Dioden<br>► Witterungsbeständige Rückseitenfolie (weiß) |
| Zellen | **60 Stück monokristalline Solarzellen** im Format 156 mm x 156 mm |
| Mechanische Belastbarkeit | 5400 Pa Auflast, 2400 Pa Soglast, gemäß IEC 61215 (erweiterter Test) |

| Leistungsklasse | Pmpp [W] | Vmpp [V] | Impp [A] | Voc [V] | Isc [A] | Rückstromfestigkeit $I_r$ [A] |
|---|---|---|---|---|---|---|
| 250 | 250 | 30,31 | 8,25 | 37,90 | 8,82 | 25 |
| 245 | 245 | 30,10 | 8,20 | 37,70 | 8,70 | 25 |
| 240 | 240 | 30,00 | 8,10 | 37,40 | 8,60 | 25 |
| 235 | 235 | 29,90 | 8,00 | 37,10 | 8,50 | 25 |
| Reduktion des Modulwirkungsgrades bei Rückgang der Bestrahlungsstärke von 1000 W/m² auf 200 W/m² (bei 25 °C): –0,33 % (absolut); Messtoleranz Pmpp ±3 % | | | | | | |

### Thermische Eigenschaften:

**Montagehinweis:**

► Siehe Montage- und Betriebsanleitung unter: www.bosch-solarenergy.de

► Montage in horizontaler und vertikaler Ausführung möglich

► Systemspannung bis max. 1000 V

► Betriebstemperaturbereich –40 bis 85 °C

### Schwachlichtverhalten:

| Intensität [W/m²] | Vmpp [%] | Impp [%] |
|---|---|---|
| 800 | 0,0 | –20 |
| 600 | 0,0 | –40 |
| 400 | –0,4 | –60 |
| 200 | –1,2 | –80 |
| 100 | –6,0 | –90 |
| Die elektrischen Daten gelten bei 25 °C und AM 1,5. | | |

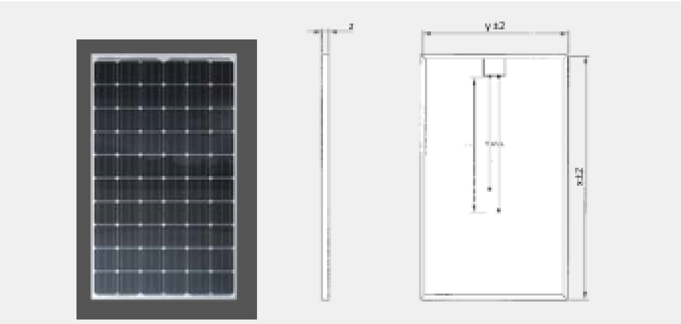
### Elektrische Eigenschaften bei STC[1]:

| Temperatur-koeffizient | TK [%/K] |
|---|---|
| Pmpp | –0,46 |
| Uoc | –0,32 |
| Isc | 0,032 |

### Elektrische Eigenschaften bei NOCT[1]:

| Leistungsklasse | Pmpp [W] | Vmpp [V] | Voc [V] | Isc [A] |
|---|---|---|---|---|
| 250 | 182 | 27,36 | 34,82 | 7,11 |
| 245 | 177 | 27,07 | 34,09 | 6,92 |
| 240 | 173 | 26,98 | 34,00 | 6,84 |
| 235 | 169 | 26,87 | 33,89 | 6,76 |
| NOCT: Normal Operation Cell Temperature 48,4 °C: Bestrahlungsstärke 800 W/m², AM 1,5, Temperatur 20 °C, Windgeschwindigkeit 1m/s, elektrischer Leerlauf | | | | |

### Abmessungen[2]:




[1] Die elektrischen Kenngrößen sind typische Mittelwerte aus historischen Produktionsdaten. Es wird keine Garantie für die Genauigkeit dieser Daten bei zukünftigen Fertigungschargen gegeben.

**Bosch Solar Energy AG**

[2] Zeichnungen sind nicht maßstabsgetreu. Detaillierte Maße und Toleranzen siehe oben.

## Appendix H: Grasshopper canvas of the PV-Simulation