

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.

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 Energieeinsparverordnung (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 wholeyear 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(m² 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,
2020/1	0/16	6/2023; Mahler	et al., 20	19)						

Energy Standard	System Boundaries	Requirements
GEG – Base Case	Building energy demand	55% less energy demand
	according to GEG, without	than the reference building
	user electricity demand	and minimum thermal
		transmittance
KfW - 40	Building energy demand	40% less energy demand
	according to GEG, without	and transmission heat loss of
	user electricity demand	55% than the reference
		building
Passive House	Building energy demand	Heating requirement < 15
	according to GEG, with user	kWh/(m² *a),
	electricity demand	Non-renewable primary
		energy PE
		< 95 kWh/(m² *a)
Zero Energy Building	Building energy demand	Annual end-user energy
	according to GEG, with user	demand = 0
	electricity demand	
Plus Energy Building	Building energy demand	Primary energy demand < 0
	according to GEG, with user	
	electricity demand	

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.

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)		

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

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 data representativeness, time-related geographical 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 CO₂-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.

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 CO2- 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)	РОСР	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

•	Table 3:	Description	n of fred	quently u	sed	impact	categories	and	assessment	parameters
((translate	ed from Go	Idstein 8	& Rasmus	ssen,	, 2018; \	Weißenberg	er, 2	016)	

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)





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 Assessment Method (BREEAM), Deutsche Environmental 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.

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	m³

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

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, wholebuilding 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.l.= 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.

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

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

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.	

			BNB	DGNB	König	Schneider-	Weißenberg
Cost Group	Cost Sub Group	Subgroup Description	(2015)	(2023)	(2017)	Marin (2022)	(2016)
	Building - Construction						
300	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	8					
	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

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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

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

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- 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.

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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.

Component	U value (W/m²K) before	U value (W/m²K) 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

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

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.

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

Table 8:	Overview	of the des	ion variants	s and the	corresponding	i enerav s	standards.
Tuble 0.	01011101		ign vanant	5 and the	ooncoponanie		nunuu us.

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

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 energyintensive 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 product stages A1-A3 (Raw material supply, transportation, building. The 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 facade, 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.

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)		
	Sewage, Water, and Gas	
410	installations	included
420	Heat supply systems	included
430	Ventilation systems	included
440	Power installations	included
	Telecommunications and	
450	information systems	included
460	Conveyor systems	included
480	Building Automation	not included
490	Other Measures	not included

Table 9. List of	included sub-cost	arouns in	the I CA
		groups in	THE LOA.

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 productspecific EPDs. If possible, generic datasets are chosen over average and productspecific. 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 CO₂ equ./m^{2*}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.

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

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

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, plugins, 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. Approach and Methodology

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.

Cost Group -	Sub Cost	Name of Cost Group	Name in the	Location in the Building	Name of the Building	Layer thickness	Amount [m2]	Sources - Documents Name	Comments	
CG	Group		Buildings		Component	[m]				
			Report		Layer					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_21104OGI- 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

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

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.

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	22600 E
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	0,240m

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

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.

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
								2 Fenster OG 1 Süd Fenster Klasse101;103- 107 Teil öffenbar

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

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.

		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, p	powder coated		
	Sash	Aluminium wing sash profile, p	powder coated		
	Glazing	Insulated glazing, triple pane			
	Connection Joint	Elastomer joint tape, polyureth	ane		
	Fittings	Window fitting for tilt and turn window			
	Handles	Window handle			
	Sun Shade	Sun protection (metal blinds) Artificial stone slab (epoxy-resin bound)			
	Windowsill interior				
	Windowsill exterior				

 Table 15: Different inputs for the two components of the "Windows South Classroom

 101;103-107"

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.

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

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

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.

Parameter	Zone	Zone	Zone Utility	Zone WC
	Classroom	Corridor	Rom	
Occupancy	0.337	0 people/m ²	0.377	0 people/m ²
	people/m²		people/m ²	
Schedule	Occu.		Occu.	
	Classroom		Classroom	
Lighting	5.72 W/m ²	4.08 W/m ²	5.72 W/m ²	5.95 W/m ²
Schedule	Lighting	Lighting	Lighting	Lighting
	Classroom	Corridor	Classroom	Classroom
Daylight control	Yes	Yes	Yes	Yes
Set Point	300 lx	100 lx	300 lx	200 lx
Service				0.75 L/hm ²
Hot Water				
Schedule				Service Hot
				Water WC
Infilatration	0.000227	0.000227	0.000227	0.000227
	m³/sm²	m³/sm²	m³/sm²	m³/sm²
Schedule				
Heating	Yes	Yes	Yes	Yes
Schedule	Classroom	Corridor	Classroom	WC Heating
	Heating	Heating	Heating	
Cooling	Yes	No	Yes	No
Schedule	Classroom		Classroom	
	Cooling		Cooling	
natural	Yes	Yes	Yes	Yes
Ventilation				
Schedule	always	always	always	always
T min -	22 -25 °C	22 -25 °C	22 -25 °C	22 -25 °C
max inside				
T min -	15-26 °C	15-26 °C	15-26 °C	15-26 °C
max				
outside				
% operable	50%	50%	50%	50%
Area				
mechanical	Seasonal	No	Seasonal	Yes
Ventilation				
Schedule	Classroom		Classroom	WC
	Ventilation		Ventilation	Ventilation
Heat	75%		75%	75%
Recovery				

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

Table	18:	List	of	different	schedules	of	the	zone	Classro	oms.	Α	fractional	schedule
repres	ents	s a ce	ertai	n % of the	availability	of	the s	system	n. A temp	oeratu	re	schedule r	epresents
the se	t poi	int te	mp	erature of	a system.	W=\	Nee	kday, '	WE= We	ekend	I, H	l=Holiday	

Hour	Oc	cupa	ncy	L	ightin	g	H	leatin	g	C	oolin	g	Ve	ntilation)	Ve	ntilat	ion
nour s of	cla	ssroc	oms		class	-		class	-		class	-		class-		C	class	-
the	Fr	actio	nal	r	oom	5	l I	room	s	r	rooms	5	l I	rooms		r	oom	S
dav				fra	actior	nal		temp			temp.		۱.	winter		SI	umm	er
uay													fra	actional		fra	actior	nal
	W	WE	Н	W	WE	Н	W	WE	Н	W	WE	Н	W	WE F	ł	W	WE	Н
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			1					
10	1	0	0	1	0	0	19	17	15	1			1					
11	1	0	0	1	0	0	19	17	15	1			1					
12	1	0	0	1	0	0	19	17	15	1			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			1					
21	0	0	0	0	0	0	17	17	15	1			1					
22	0	0	0	0	0	0	17	17	15	1			1					
23	0	0	0	0	0	0	17	17	15	1			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.

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

Table 19	9: List of	additional	simulation	parameters

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.

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		

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

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

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

Osmasant	Innute	Value
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	1.1
	current	

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

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.

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

Table 22: Design decision	s and corresponding energy	demand of the variants.
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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.

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

Table 22.	Overview of t	ha different	ovpandod sy	vetom boundarios
I abie 23.			expanded 5	ysiem boundaries.

Application of the Methodology
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 $kgCO_2$ -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 CO₂-Equ. emissions in the electricity mix stay constant.

Table 24: LCE in kgCO2-Equ./m ² of the case study divided into EE and OE for a referen	ce
study period of 50a.	

	Calculated values for the construction part (Sum	GWP
	01 Modules A1 - A3, 62-64, 63, 64)	[kgcoz-Lqu./iii-]
	Sum of Cost Group 300	327,3
	320 Foundations	1,7
	330 Exterior Walls	161,7
	340 Interior Walls	64,4
Ш	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
	Calculated values for the operation Energy	-226,0
ш	demand (B6)	
0		
	-	
	Sum	338,7
U U		

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).

Results



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.

	Base Case	Varia	ant 2	Vari	ant 3	Varia	ant 4	Vari	ant 5	Varia	ant 5
	GWP [kgCO2- Equ./m²]	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	-

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.

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 guicker 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 bestperforming 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 kgCO₂-Equ./(m²a). The base case emits 11.29 kgCO₂-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: 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.

Results

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.

Limitations

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

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

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Menge (m2) Menge Neu (m1)	7.4	7,4	7.4	7.4	7,4	225,6	225,6	225,6	225,6 L	276.6	225,6	225,6	0'077	225,6	225,6	27,5	1 400	27.5	27.5	27,5	27,5	27.5	5011	118.9	118,9	118,9	118,9 E	118,9	118 D	21,8	21.8	21.8	21.8	21.8	21,8	21,8	21,8	21,8	<i>a'a</i>	6.69	6'69	6,69	6'69	60.0	206	
Schichtsfoke (m) = m/m*	0,003	0,045	0,00	0,25	0,12		0,003	0,002	0,001	0.000	0,29	0,12	120,0	0,027	0'04			0.003	0,001	0,045	0,25	0,12		0.01	2007	0,028	0,003	0,003	0.05	00'n	0,01	0.045	0,001	0.028	0,004	0,001	0,12	0,05		0,003	0,045	0.001	0,25	0.12	N, 16	
Baurele Schrittbarechnung	Kieber	Celchumsulfalfließenestrich	TED descert	Sib-Flachdecke	Mineralwolle	Klasserraume utter Keller	Lindeum	Keber Catarmentiotietensonentroh	TSD Fale (Weberfloor 4955)	1 eichteurscheich	Remy-Decke	Mineratwold Diverse Criseron	17000 0 Stable	Regps CD6027	Capsplatten DFR	WC		r mouri Kieter	Abdichlung	Calizumsuitattießenestrich TSD //cv/ac/	Stb.F.lachdocko	Minerateda	Puches	Fliesen	Kietori Potriumsulfattiatianastrich	VIP Akustik EVP	TSD Folie (Weberfloor 4955)	L eichteursgleich Stahlbeten	Kine	WC Breach Ost	Flesen	nvecer Cedziumsulfattije6 enestrich	Trennfolie	VIP Akushk EVP TEO fizzuer	Leichtausgleich	Epodhardampfbremse	Stahlbeton	Kios Flantuorise		Lindeum Kietber	Calziumsulfatfis&enestrich	Tremritolie TSD (Isover)	Stahlbeton	Minerakonia	real men devices Werktstume	
Zuordinung bzw. Lage						002 - 007 Klassenräume - 083 084 Flur										070-074 WC Schler, Putznaum						DOB 1 shekitaka DOD LID	uus Lefirkuche, uus NK Lefirküche							075-079 WC Boreich Ost								001 Toylios Markan	HONIGAL CORVEL 100						010 Technik, 011 Maechinonraum, 012	Technik
aufelle-seichnung Luut Buuteik etalog)						H 3.02 Fußboden Interkellert - Kinsse										H 3.04 Fußboden Interkellert -	euchträume West					12 M. T. Phadan	1 3.03 r utsoooen jegen Erdreich - Verknimme							H 3.07 Fußboden Jegen Erdreich -								1 3 DR Fulthorton	interkellert - Kinsse						1 3 09 Fußboden mann Erdreich	Netkräume
Bauteligruppe E Name (Decken UG-FG										Decken UG-EG	-					antine 117 E.F.								Jocken UGEG								Increan LIGEG							Jecken UGEG	. 2
Bautell-KG	352	352	200	351	363		352	352	362	656	351	363	222	363	363	-	and a second	352	352	352	361	363		362	26.7	362	362	362 361	EWE		352	362	352	352	362	352	351	363		362	362	362	361	898		
Bauteilgruppe_K	350	350	380	350	350	350	350	350	350	360	350	350		350	350	350		350	350	350	350	350	DCr	350	250	350	350	350 350	Une	360	350	350	350	350	350	350	350	350	~ ~	350	350	350	350	350	350	

Literatur

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Bauteligruppe_K G	Bautell-KG	Bauteligruppe Name	Bauteiltezeichnung (laut Bauteilketalog)	Zuordnung bzw. Lege			nger Neu Fmil		Description for working out of participants. Plane and Monourgen vice Jakyani	
350	352				Kieber	0	208.0	Filesenkleber (de) en		
100	362				Celizumsullatiletisterestrich Trennfolie	0.045	208,0	Cenciumsultatestrich (de) PE-Nonsenfolie zur Abrüchtung (de)		
80	352				VIP Akustik EVP	0.028	208.0	existnes EPD. EPD-POR-20200138-IBC1-DE		
120	362				TSD (Isover) Envidentificance	0,012	208,0	Mineralwolie (Boden-Dämmung) (de) Dannthramva PE (da)		
850	361				Stahtbeton	0,12	208,0 T	ransportbeton C30/37 (de); Bewehrungsstahl (de))	Gesant Stahlbeton Neu Außerwand Berechnung siehe Tabelle Übersich	ande sicht-
100	16.9				Kin	0.06	0.000	1	Flachen Volumen Neu	
1 000	COC					co'n	n'en7			
423	423	Heizdocken		Heizdecke EG					Deckenspreget 1A 2173EG 1F	
123	423				Paneti reizooske muu Panool Hoizdooke Rehau	0,02	123,1	Extern uper sockelbeitrag Unks Extern über Sockelbeitrag QNG		
Erdgeschoss Anbau con		Ausserwände	AW Hochkehzienel	Aussenwend Nord West-	Receitessade - Dénomino Hart				Wandauftsution 1A 21003FG-2 P Schnitt Hotes = Raurthöhe + Häftla der	a d
			EPS Putz	Gang	e e e e e e e e e e e e e e e e e e e	0.040	10.0	the second second states are the	1A 21013SDD H Decken/Boden	
	335				Nurtuzhartzputz Warmodarmnung Hart Neu EPS	0,015	150.8 F	Kunstharzbuiz (de) en de PS-Hattscheum (dreu Rohdichte 20 bis 25 kolm?)		
30	331				Mauerwerk	0,3		Mauerziogel (ungofülit) (de)	Berechnung Mauerwerk Nau in Übers Fleicher Volumen neu.	sersicht
330	336				Putz	0,01	163,8	Gipspultz (innen) (de)		
8		Ausserwande	AW mit Lockplate	Aussenwand - West	Aussemmand West				Grundriss: 1A_21003EG-2_P; Schnift: 1A_21018SHH_F; Ansicht Oat	
100	335				Kuntzhertzputz Vakiilimisantwerbeleneert VID/EDS	0,015	44,B 44.B	Kunstharzputz (do) en do externes EPD: EPD: PDB -20200136-IBC1-DF		
100	331				Mauterweek	0,3		Mauerziegel (ungeluit) (de)	Berechnung Mauerwerk Neu in Übers	persicht
30	336				Putzmörtei	0,01	44,8	Gipsputz (innen) (de)	Flachen Volumen neu	
330		Aussenwände		Aussonwand Süd	Rogoffassado - Súd				IBP_Senterung Untendschule/Srundnss.	
200	305				Kunzherzpulz Mineralwolfa	610,0	0'/0	Kunstharzpulz (de) en de Mineerkede (Fassaden-Dimmuno) (de)		
330	335				Sockeldsmmphatte WDVS	0,2	12,825	Extrudictor Polystyrol Dämmstoff (XPS)		
130	331				Mauerwerk	0,3		Mauerziegei (ungefüllt) (de)	Berechnung Mauerwerk Neu in Ubers Electreen Volumen neu	sersicht
330	336				Putz	0,01	57.0	Gipsputz (mnon) (do)		
330		Aussenwände		Aussenwand Sud TRH	Regelfassone - Sut TRH				IBP Semierung Unlandschule Grundriss 1A_21003EG-2_P: Schmit AA, HH: Sockel Defeke	
330	335				Kuntzharzpulz	0,015	8,8	Kunstherzputz (de) en de	C10000	
330	335				Mineralwole	0,23	8.8	Mineralwolle (Fassaden-Dammung) (de)		
000	331				Socketemprate VLVS Mauerwork	0.175	1,940	Extrudenter Polysityrol Demmistort (XPS) Manierzieczei (uncerbilith) (de)	Berechnung Mauenwerk Neu in Ubers	persicht
									Flächen Volumen neu	
8		Aussonwando	AW Hochochziegel EPS Putz	Aussonwand Nord - I Kri Ost	Nogoriassado - Danmrung Han				Grundins: TA_21004L5-2_P. Schmitt. 10006 Haummonic Friedfro dor 1A_21018SHIFT, 1A_21010SAQ_H, Detail Scotad	a.
330	335				Kuntzhertzpulz Mermedemmunn Hart Man EDS	0,015	17.0	Künstharzputz (de) en de Bis Mantechanian (zerai, Bishelichte 20 his 26 koheit)		
100	335				Sockeldermplate WDVS	0,2	2,134	Extrudicitier Polystyrol Dämmsfoff (XPS)		
330	331				Msuerwerk	0,175		Mauseziegel (ungefult) (de)	Berechnung Mauerwerk Neu in Übers Flächen Volumen neu	persicht
330	336				2nd	0,01	18,2	Gipsputz (innen) (de)		
330		Aussenwände	nicht vorhenden	Aussenwand Nord Gang	Dammung mit Isower Unter Fensier				Gundliss: 1A_21003EG-2_P_Schnitt: Hohe = Raumhöhe + Haifte der 1A_21018SHH_F_1A_21010SAA_H; Deteil Sockei Boden	ų
330	335				Kuntzharzpulz	0,015	25,6	Kunstharzputz (de) en de		
200	305				ISOVER UILITIABE Sockeldämmpkatte WDVS	0,2	7,274	Minefalwore (r.sosauer-uarrinarg) Extrudierter Polystyrol Dammstoff (XPS)		
330	331				Mauerwerk	0,175		Mauerziogel (ungefult) (de)	Berechnung Mauerwerk Neu in Übers	sersicht
30	336				Innenausbeu	0,08	25,6	1	Neicht abgeblidet Kenumen neu Neicht abgeblidet Kenen Ahngaben zu	unz u
330		Stutzen	nicht vorhanden	Statzen Überdechung Sud	Statzen Überdachung				Grundster, 1A, 21003EG-2, P, Schmitt 1A, 21018SHH, F, 1A, 21010SAA, H; Detail	
330	335				Kuntzhartzputz	0.015	14.7	Kunstherzputz (de) en de	500KG	
330	335				Mineralwole	0,08	14,7	Mineralwolle (Fesseden-Dammung) (de)		
330	12				Beton	0,4	Trar	isportbeton C25/30 (de); Bewehrungsstahl (de) en de	Gesant Stath before New Automatics New Automatics Benediting state 1 Tables, Ubersch Flacten Volimen Neu	lande. sicht-
340		Innenausbeu		Anstrich + Putz	Anshich und Pulz Wande Innerseite (Blau Marker!)				Wandaufbaulan 1A_21103EG2_0, Schritt. 1A_2103ESHH F	
340	345				Anstrich	0,0025	279,6	Innerfarbo Dispersionsfarbe scheuerfest (do)		
340	345				Putz	0,01	279,6	Gipspult2 (innen) (de)		

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ondenne. Kom meriter / Annerkung angen angen	0, Schnitt M8SHH_F	Vibau	L	elf.		0; Schnift Höhe Raumhöhe + Häfte der Doorwatsden		Borachnung Mauerwerk Nou in Ubersicht	Flachen Volumen neu 0. Schnitt: Der Brendstreifen Zieht sich an der Cesamten	SCG_F, Außerwand Nord mit EPS entitang auch überhalb der Fenster		0, Ansicht		Berechnung Mauerwerk Neu in Übersicht	Flachen Volumen neu	_0, Anscht		Berechnung Mauerwerk Neu in Übersicht		211040G1 Wht , l'enster				Gesami Stahlbeton Neu Außerwande	Flachen Volumen Neu	Neu	Gesant Stahbaton Nau Außerwande Berechnung stehe Tabelle Überscht- Flachen Volimmen Nau	0, Schnitt	Wbau		0, Schmät			_0, Schnett:	D. Eastraiter	u, scrimue. SGG_F	31-1_0. G,		
Content (file: pitts all a verse Dokumente versenian und be Plane mit Messangen etc. al	Wandaufbaulan. 1A_21103EG2 1A_21018SHH_FSohnitt 1A_210	Trockenbauarbeiten: 10 SR V Davisions sitta	Distriction of the second	Leckenspeger 1A_21/3EV		Wandaufbauten: 1A_211040051-1	1 0000 014 12		Wandsufbeden 1A 21104001-1	1A_21013SDD_H, 1A_210165 1A_21014SEE_G		Wandaufbauten: 1A_21104.0G1-1 BB	8			Wandaulbautan: 1A_21104OG1-1 BB				IBP_Samonung Uhlandschulo; 1A. 1_0(Wandsutbauton); Ans 1A_21022AS_I, Schnite AA.IT Details						Obersiocht Flachen Volumen		Wandaufbauten: 1A_211040G1-1	Trockenbauarbeiten. 10 SR V	ANAGIOVENAN	Wandsulbauten 1A_211040G1-1	1A 21013SDD H pdf		Wandaufbauten 1A_211040G1-1 1A_21013SDD H.pdf	Mandouthantoor 18 71104005 4	1A_21014SEE_G, 1A_210145	Wandeutbeuten: 1A_2110400 Schmite: 1A_21014SEE_	1A 2101450G F	
a LCA Dimment		Gipsferserplate (10mm) (de)	Steinzeugfiesen glasiort (de)	Extern über Sockelbetrag QNG	Extern uber Sockelbetrag QNG		Kunstharzputz (de) en de	EPS-manscheum (greu, koneichie zu bis zb kgim?) Mauezriegel (ungefult) (de)	Gipsputz (nnen) (do)		Mineralwolle (Fassaden-Dammung) (de) Konsthuezeuts (da) an da	Local state sectors (Jack) and . Con	Kunstherzputz (de) en de	Maueziegei (ungefulli) (de)	Gipspulz (nnen) (do)		Kunstherzputz (do) on do externes EPD- EPD-POR-20200138-IBC1-DE	Mauocziegei (ungelütti) (de)	Gipspulz (nnen) (de)		Photovoitaiksystem 1000 kWhim2*a ohne Stromgutschrift (do)	Kunstherzputz (de) en de	Mineralwollo (Fassaden-Dârmung) Mineralwollo (Fassaden-Dammung) (de)	Transportbeton C25/30 (de); Bewehrungsstahl (de) en de	Chambred & Denning View	(an) (an)	Transportbeton C25/30 (de), Bewehrungsstehl (de) en de		Gipsteserplate (10mm) (de)	Steinzeugfitesen glastert (de)	Innenfarbe Dispersionsfarbe scheuerfest (de)	tion of the Physical Content of the second second	Innertiarbo Urspersionstarbo scheuerties, (ue) Gipspulz (innen) (de)		Inner/larbe Dispersionsfarbe scheuerfest (de)		Auminumblech (de)	CIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool	(de)
Menge (m2) Menge Neu (m1)		43,6	96,8	10.8	68,0		150,8	0/061	163,8		13,0		49,0	0'Rtr	49,0		35,9	a164	35,9			151,9	77.9		1010	R 101			84,9	118.5	30,8	2 FUE	724.5		24,8		7.98	12,4	
S chicht diche (m) = m'm'		0,15	0,01	0.02	0,02		0,015	0,3	0,01		0,01	2000	0,015	0,3	0,01		0,015	0,3	0,01			0,015	0,2	0,3	0.04	D'D	0,3		0,15	0,01	0,0025	0.0004	0,01		0,0025		6200'0	0,015	
Bauntisk Schrichtbezeichnung	Innenauskeu	2-lagig RIGIDUR	FlixSon	Paneel Heizdecke MCI	Paneel Heizdecke Reheu	Regelfæssade - Dämmung Hart	Kuntzhartzputz	warmedarmung nan weu ciris Mauerwerk	Pult. Brandstreifen		Minerawole WLG 033 Kintthattruitz	Regottessade - WC/I RH	Kuntzhartzputz	V anounisationexistication virtuals	Pulzinozelal	Rogolfassada - Fassado West	Kuntzhartzputz Vakrumsendwichelement VIP/EPS	Mauerwerk	Putzmörtei	Repolitassade - Sud (Dammung Abwechscind)	PV-Anlage	Kuntzharzputz	Iscover Ultradio VDVS rht Storwolle	Belon	1 ¹¹	g Austeesserung Ausserwand	Stattbeton C20.75	Innenausbau	2-lagig RIGIDUR	Fließen	Anstrich Anstrich und Putz Wande Innerseiße (Blau Markiert)	America	Anstrich Putz	Anstrich Füllung (Orang Marklet)	Anstrich a forficience data at A	(Status) (Summinguan)	Beschichtung Metall Hybridwand RIGIDUR, 1GKB (grun)	CKB	
Zuordnung bzw. Lage	wc		the state of the s	Herzoecke FUs		Aussenwand Nord West-			Aussenwand Nord West -	Gang		Ausserwand - WC/TRH				Aussenwand - Klassenzimmer West				Aussenwand S0d						Aussenwand - Ausbesserung		wc			Anshich + Putz			Anshich	A detaileduide one	M UGHUT KUORUUTIG	Klassenräume, Vvorraum Musik		
Baufailbezakhrung (laut Baufeilketalog)						AW Hochlochziegel					V1 / AW01.	AW mf Lockplate				AW mit Lockplate																							
Bauteligruppe Name	Innenaustieu		1 stratistics to sa	Herzoecken		Aussenwände			Aussenwande			Aussenwände				Ausserwände				Aussonwände						Aussenwande		Innonausbau			Internausbeu			Innenausbeu	the second second second	Introlation	Innenwand		
Bautell-KG	-	345	342	423	423		335	331	336		336	-	335	331	336		335	331	336		442	335	335	331	336	000	337		345	342	342	740	345		341		34	362	
Bauteligruppe_K	340	340	340	423	423	330	330	330	330		330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	340	340	340	340	340	340	340	340	100	340	350	
Bauteligruppe_K	Bautell-KG	Bauteligruppe Name	Bartellozzachhung (lauf Bartelkatalog)	Zuordnung bzw. Lage	Bauteri-Schröttkozeichnung	(m) = m'm' Mo	etcA Dam maj se Nau maj		Downstrate version frame and	Kommerika / Anmerika /																													
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01		Innernand		Neues Mauerwerk & Beton					Wandaufbauten 1A_21040001-1_0, Schnite 1A_21014SEE_0; 1A_21014SEG_F; Ühentsite Fätchen Volumen Neu																														
40	341				Mauerwerk	0,2	Mauerziegei (ung	gefült) (de)	Berech	nung Mauerwerk Neu in Übersicht Flachen Volimmen neu																													
40	341				Beton C2025	0,2	Transportbeton C25/30 (de), Be	wohrungsstahl (do) on de	Berech	nung Mauerwerk Neu in Übersicht Flinchen Volumen neu																													
60		Decken EG-1.0G	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 Bodenaurthauten: 1A_210940C1-1_A; 3.10 Details; 1A_22680_0																														
55	352				f JoSan Krótow	0,01	36.1 Steinzeugflesen (plastert (de)																															
00	352				Abdichlung	0.001	26.1 PE-Noppentole zur A	Abdichitung (de)																															
20	352				CelcumsulfatheSeriestrich	0,045	35,1 Calciumsulfates	strich (de)																															
200	362				I formitole TSD (forwar)	0,001	35.1 PL-Roppeniole Zur A 35.1 Minoreliado (Rocion I	Voorchlung (de) Dismeningi (de)																															
8	351				Ripppendecke	0,33	36,1	Panal Weinstein can																															
8 8	363				Minerakole Grundprofei Rigips CD 60/2	0,05	36,1 GIPSPLATTE NACH DIN EN 5:	20 UND DIN 18180 / Tool																															
80	363				Tragproofil Págips	0,027	(de) 36,1 GIPSPLATTE NACH DIN EN 5.	20 UND DIN 18180 / Tool																															
89	363				Glastno: F	0,015	(de) 36,1 GIPSPLATTE NACH DIN EN 5: 6451	20 UND DIN 18180 / Tool																															
60	363				GKBi	0,0125	36,1 GIPSPLATTE NACH DIN EN 5.	20 UND DIN 18180 / Tool																															
50		Decken EG-1.0G	H 4.03 Fußboden Klassenräum	Klassonräumo 101-114	Klassonråumo		13,3	m	16 Bodonaufbaulton; 1A_21094OG1 1_A & 1A_21094OG1-2_A, 3.10 Details.																														
80	362				Lindeum	0.003	713,3 Linoloum	(00)	1A 22680 0																														
60	362				Kieber	0,002	713,3 Kleber für Gipsp	katten (de)																															
200	362				Calciumsulfatfließenestrich Trannfolia	0,045	713.3 Calciumsulfates 713.3 DE.Nonnenfolia 711 &	strich (de) Metebernen (de)																															
50	352				TSD (Isover)	0,012	713.3 Mineralwole (Boden I	Dörmung) (de)																															
050	351				Ripppendocko	0,33	713,3 Alternation (Encoded)	 Dimensional (dat) 																															
80	363				Gundprofel Righs CD 60/2	0,027	713,3 GIPSPLATTE NACH DIN EN 5/	20 UND DIM 18180 / Tool																															
8	353				Tragproofit Ngps	0,027	713,3 GIPSPLATTE NACH DIN EN 5/	20 UND DIN 18180 / Lool																															
20	353				Glastoc F	0,015	713.3 GIPSPLATTE NACH DIN EN 5.	20 UND DIN 18180 / Tool																															
80		Decken EG-1.0G	H 1.05 Flur	Flur 180, 183-184, 188	Flur 1.0G		(db) (db)	6	.6 Bodensutbauten; 1A_210940G1-1_A &																														
									1A_210940001-2_A, 3.10 Details, 1A_22680_0																														
88	362				L incleam	0,003	227,6 Linoleum	(de)																															
8	362				Catzumsuffatfhe&enestrich	0,045	227,6 Calciumsuffates	strich (de)																															
50	362				Trennfolie	0,001	227,6 PE-Noppenfole zur A	Abdichtung (de)																															
88	362				I SU (150/61) Leichtausgleich	0,02	227,6 Minerativotie (Boden- 227,6 Zementimoti	el (de)																															
88	351				Ripppendecke	0,33	227,6																																
3 5	363				Grundproteil Rigips CD 60/2	0,027	227,6 GIPSPLATTE NACH DIN EN 5:	20 UND DIN 18180 / 1 00																															
20	353				Tragproofil Rigps	0,027	227.6 GIPSPLATTE NACH DIN EN 5.	20 UND DIN 18180 / Tool																															
50	363				Câtasroc F	0,015	227,6 GIPSPLATTE NACH DIN EN 5:	20 UND DIN 18180 / Tool																															
23		Heizdecken		Heidecken zwischen EG -			(an)		Deckenspiegel: 1A_21073EG-1_F																														
22	423			1.00	Paneel Hoizdecke MCI	0,02	66,6 Extern liber Sockel	thetrag QNG																															
Obergeschoss An.	423 X0U				Paneel Heizdecke Rehau	0,02	140,1 Extern uber Socket	Ibetrag QNG																															
30		Aussenwande	AW Hochlochziegel EPS Putz	Aussenwand Nord West- Gang	Regelfacsade - Dämmung Hart				Grundriss: 1A_210040G1-2_N; Schräft: Ho 1A_21010SAA_H	ohe = Raumhohe + Halfte der Decken/Böden																													
8	335				Kuntzhartzputz	0,015	72,1 Kunstharzputz ((de) en de																															
30	331				warmoustimung naruvou Lins Mauewerk	0,3	Maueziegel (unc	petult) (de)	Berech	nung Mauerwerk Neu in Übersicht																													
00	338				414	0.04	73.1 Cinerada (inne	an) (da)		Flächen Volumen neu																													
8		Aussenwande	AW mit Lockplate	Aussenwand - Ost	Aussenmand Ost	1 m ² m		fam) fra	Grundriss 1A 2100MOG1-2 N, Schnitt.																														
30	335				Kuntzheitzputz	0.015	46,4 Kunstharzputz ((de) en de	A ZIUNOWA TI, MINGH COM																														
30	335				Vakuumsandvächelement VIP/EPS Manerweck	0,09	46,4 externes EPD: Erru-rrunc- Mauerziedel func	20200138-IBC1-DE minititi (do)	Barach	nund Mauenwerk Neu in Übersicht																													
-	100					~!~	5	South (www.		Flachen Volumen neu																													

Barteligruppe_K	Bautell-KG	Barteligruppe Name	Bautellbezaichmung (laut Bautelik etaloo)	Zuordnung bzw. Lage	Bautrel's Schichthooseichnung	Soutienteicie Menge (m) = m/m* (m2) (m7) (m7)	+LCALDIMenter	Gualencijker skale ja ke verwandelen Deutensine kan se verwandelen Deutense verwaaren uid bestenden Plane int Mestaugen ets ablegen
330	336	1100 providendo		A reservativel S (int	Putzmortei Baronifessewis - Sint (Dimmunn Altwordsschut)	0,01 48,4	Gipspulz (mnen) (de)	Gumbies 1A 21000051.2 II Scheilt
3					/numeroname. Burnument) man annormungBour			1A 21010SAA H. Ansicht Sud
330	442				PV-Anlage		Photovoltaiksystem 1000 kWh/m2*a ohne Stromgutschrift (de)	
330	335				Kuntzhartzputz	0.015 55.8	Kunstherzputz (de) en de	
330	335				Isover Unmare WDVS mit Steinwolle	0,2 14,3 14,5	Mineralwolle (Fassader-Darmung) Mineralwolle (Fassaden-Darmung) (de)	
330	331				Beton	0,3	Transportbeton C25/30 (de), Beweitrungsstahl (de) en de	Gesant Stahboton Neu Automende Borechnung eine Taketer
330	336				Zind	0.01 55.8	Gipsputz (amen) (de)	LISCHEL VOUTION NOU
340	-	Innonausbau		Anstrich + Putz	Anstrich und PulZ Wände Innenselle. (Bisu Markert)			Wandsufbauton: 1A_21104OG1 2_0; Schnitt 1A_21010SAA_H.
340	345				Anstrich	0,0025 271,5	Innertarbe Dispersionsfarbe scheuertest (de) Givernist (annon) (dio)	
340	-	hnenausbeu		Anstrich	Anstrich Fidlung (Orang Markeet)		faces (i source as) mandredge	Wandaufbandan. 1A_21104051-2_0; Schnätt 1A_210105AA H.
340	341	nenausbeu		M etallerkleidung	Anstrich Metterkverdeidung (Park)	0,0025 147,9	Innerfarbe Dispersionsfarbe scheuerfest (de)	Wandsuthsuten 1A 21104001-2 0: Schnitt
ł				Fundamental control of	form at Restructure restructure			1A 21010SAN H;
340	341	nemwand		Klassenräume, Wromaum	Beschichtung Metall Hybridwand RiGIDUR, 1GKB (grun)	0,0025 8,3	Aluminiumblech (de)	Wandsurbauten: 1A_211040051-2_0; Schmitt
340	342			Musik	GKB	0,015 74,6	GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool	1A 21010SM H:
340	342				Riodur (entacio)	0.075 74.6	(do) Cinstesentiathe (10mm) (de)	
3110		ривмини		Neues Mauerwerk & Beton				Wandeutheuten: 1A_21104OG1-2_0; Schnitt. 1A_3101055AA_H-
340	341				Mauerwerk	0,2	Mauerziegei (ungefülti) (de)	Berechnung Mauerwerk Neu in Übersicht Flie Aren Vinimen neu.
360		Dach	Bautellaufbaut Dach EPS 031	Anbau Dach Ausrichtung Stid	Dech Sud			Grundhis: 1A_21004061-2.N; Schnitt: AA, HH: Details Dach: 1A_22601 E:
Los					DM. A shows		Directorial interactions of CCC MADS in CFs of no. Channel doubled	Schehtaufbau (BF + + + + + + + + + + + + + + + + + + +
100	44.2				PV Amago		Photowolarisystem 1000 kWhim2 a onno Stromgulschnit (de)	1/_21304LP4_B
360	363				Dachabdichtungsbahn Polyolofin owoTowhsch EDS 031	0,01 246.	8 TPO/FPO Dach-und Dichtungsbahn (de) E PS Hadocheum (Bobelehen 15 kolor)	
360	363				Dampfspere	0,0025 246.	8 Dampfbremse PE (de)	
360	364				Romy-Decke Gaskartenplata	0.2 246. 0.02 246	8 GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool	
360	26.4					200	 A International Control of Control of Control 	14 21074/001-2 E
360	364				Gastroc F	0.015 187.	3 Opsteuplete (Feuerschutz, 12,5mm)	1A_21074061-2.F
360	364				Akus8kdecke	0,02 187.	3 Nicht dargestellt. Kein Datensatz vorhanden	1A_21074DG1-2_F
423	423				Paneel Heizdecke Rehau Paneel Heizdecke MCI	0,02 78.	3 Extern uber Sockelbetrag QNG 5 Extern über Sockelbetrag QNG	1A_21074051-2_F 1A_21074051-2_F
360	-	Dech	Bautellaufbeut Dach FDS 031	Arbau Dach Ausrichtung Nord	Dech Nord			Grundriss: 1A_210040G1-2_N; Schnitt: AA, HH: Dravis: Drave: 1A_22601 E-
444	440							Schichteuthau IBF
360	363				Decretoriation and a construction of the const	0,2 133,	3 EPS-Hartschaum (Rohdichte 15 kg/m ³)	
360	363				Damptsperre Remv. Decke	0,0025 133	3 Dampfbremse PE (de) 3 GIPSPI ATTE NACH DIN FN 520 (IND DIN 18180 / Tool	
Caso C	Vac					167 OV V	District Control PER Party	
360	364				Coposition amolia Minor almola	0.05 88.	 Dumptoremse rt. (de) Mineralwalie (Boden-Dämmung) (de) 	1A 21074DG1-2 F
360	364				Giastoc F	0,015 88,	5 Gipsbauplaite (Feuerschultz, 12,5mm)	1A_210741061-2_F
360	364				Akusikidecke Paraal Haizdanka MCI	0,02 88	 Nicht dangestellt. Kein Datensatz vorhanden Evtern uber Sovkalheiten ONG 	1A_21074061-2_F 1A_21074061-2_F
423		leizdecken		Heizdecke zwischen EG-		Lynn -	· · · · · · · · · · · · · · · · · · ·	Deckerspiegel. 14_21073EG.2_H
423	423			1.00	Paneel Heizdecke MCI	0,02 10.	8 Extern uber Sockelbetrag QNG	
423	423				Paneel Heizdecke Rehau	0,02	3 Extern uter Sockelberrag QNG	
2. Obergenormon	V	lussenwände	AW Hochlochziegel	Aussenwand Nord - Gang	Receitessade - Dämmung Hart			IBP Sanierung Uhlandschule:
UCC	326		EPS Putz		Kuntethantha	0.046	16 and the second second starts and the	1A/211050G2 0 dwg (Wandoufbauten)
330	335				Withmediammuno Hart Neu EPS	0.3 96.8	FPS-Hartscheum (orea: Roholohie 20 his 25 kolm?)	
330	331				Mauerwork	0,3	Mauerziegel (ungefull) (de)	Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu
330	336				Dutz zind	0,01 96,8	Gipsputz (innen) (de)	
330		Aussenwände		Ausserwand S0d	Regeitassade - Sud (Dämmung Abwechseind)			IBP_Satienung Uhlandschule; 1A/211050G2_0.0wg (Wandaufbauten);;
330	442				PV-Anlage		Photovoltarksystem 1000 kNVhim2*a ohne Stromgutschrift	Ansicht 1A 21022AS 1
131	305				Kund Antizatiz	0.015 142.0	(do) Kunstharzhuitz (de) en de	

Kommenter/Ammentung		Gesamt Stahtbeton Neu Außerwande. Berechnung stehe Tabelle: Übersicht- Flachen Volumen Neu			Berechnung Mauenwerk Neu in Übersicht	Flächen Volumen neu														Berechnung Mauerwerk Neu in Übersicht Flächen Volumen neu																							
Confination from a line wave wavefactory of the and the wavefactory of the control of the contro			0 COODIE 11 material adverter	0 POVICI I P VI I IMPROVIDED AN			Wandaufbauten: 1A. 21105002_0	Irockensauaroenen. 10 SK wisau Revisionsakte		Wandaufbautan: 1A_211050G2_0, Schnitt: 1A_21013SDD_H pdf		Wandaufbauten 1A_211050G2_0, Schnitt	TA 210135500 H DOT	Wandartbauten 1A_21105002_0; Schnitter 1A_21014SEE_G; 1A_21014SGG_F	Wandaufbaulan:1A_211050G2_0. Schnitte.	14_210145EE_0, 14_21014500_F		111 1 0 1 11 010000 0 0 1 10	Wandaufhautan 14_21105002_0, Schnitte 1A_21014SEE_G, 1A_21014SGG_F		3.6 Bootsonification 1A 21005075 A 3.10	Details: 1A 22680 0						Deckenspiece: 1A 210740G1-1 F	3.6 Bodonaufbauten; 1A_210950G2_A; 3.10 Dotais: 1A_22690_0							Deckenspiegel 1A_210740G1-1_F	3.6 Bodenaufbauten; 1A_21095002_A; 3.10 Details; 1A_22680_0						
a.C.A.Damonee	Mineralwolle (Fassaden Dämmung) Mineralwelle (Fassaden Dämmund) (44)	versommer (r cosocier community) (up) Transportboton C25/30 (do), Bowehmungsstahl (do) on do	Gipspulz (innen) (de)	Kunstharzputz (de) en de	externes EPD: EPD-POR-20200138-IBC1-DE Mauerziegel (ungefulit) (de)	Gipsputz (innen) (de)		(alpstesserptietre (1 umm) (ae)	Sterrzeughesen glassert (de) Innenterbe Dispersionsfarbe scheuertest (de)		Innerfarbe Dispersionsfarbe scheuerfest (de)	(an) (invite) mededin	Innerfarbe Dispersionsfarbe scheuerfest (de)		Akiminiumbisch (de)		CIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de)	Gipsfaserplatus (10mm) (de)		Mauerziegel (ungefulti) (de)	Transportbeton C25/30 (de): Bewehrungsstehl (de) en de		Linosum (06) Kleber für Gipsplatten (de)	Calciumsulfatestrich (de)	Priz-froppeniole Zur Abardhung (de) Mineralwolle (Boden-Därmung) (de)		Mineralmolle (Fassaden-Dammung) (de) CIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool	(de) Extern uter Sockelbetrad ONG		Linoleum (de)	Klebber für Gipsplatten (de) Calciumsuffatestrich (de)	PE-Noppenfolio zur Abdichtung (de)	Mineratiwotie (Booten-Liammung) (de) Zementmörtel (de)	ent Ganth ann an constantion	MineralMolie (Fassaden-Utimmung) (de) GIPSPLATTE NACH DIN EN 520 UND DIN 18180	Extern uber Sockelbetrag QHG		Steinzeugfiesen glasiert (de) Flieserkieher (de) en	PE-Noppenfole zur Abdichtung (de)	Calciumsuffatestrich (de) DF Nonnenfolie zur Abdichtung (de)	Mineralwolle (Boden-Därmung) (de)	Misseeshoodia (Ensessation-E) internance) (clas)	GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (60)
Manga Manga Ing	74.0	0110	142,0	62,2	62,2	62.2	0.00	6'/0	21.7		798,4	r an	249,6		17,3		91,8	91,8		58,2	7.0	- T	442,1	442,1	442,1	442,1	442,1	128.4	153,4	153,4	153,4	153,4	153.4	153,4	153.4	80,3	1.4	7.4	7.4	7.4	7,4	7.4	¥2
(m) = m'm'	0,2	03	0,01	0,015	0,09	0,01	0.40	ct'n	0,015		0,0025	0'0	0,0025		0,0025		0,015	0,075		0,2	0,2		0,002	0,045	0,001	0,33	0,05	0.02		0,003	0,002	0,001	0.01	0,33	0,05	0,03		0,01	0,001	0.045	0,02	0,33	0,015
Baureir (Schichteorechnung	Isover Ultimate	Betch	Pute	Runtzharzouze w curren	Vakuumsandwichelemant VIP/EPS Mauorwork	Putzmortei	Innonausbau 2. Social Distribution of Second Accounting to the Second Accounting of the Second A	Z-lagig KristicoK (sipsprassipatian)	Flacten Anstrich	Anstrich und Putz Wande Innenseäe (Bleu Markiert)	Anstrich	Anstrich Fullung (Orang Markiett)	Anstrich	Mettalverkleidung (Pinik)	Boschiehtung Motell Hybridweind RilsiDUR, 1GKB		GKB	Rigdur		Mauerwerk	Biston C20/25 1 indiam Broten & Atreatizante Darke		Linceum Kieber	Calziumsulfatfließenestrich	TSD (lscver)	Rippendecke	Mineratwole Clastoc F	Paneel Heizdecke Rehau	Lindeum Bodon & Abgehängte Decke	Lindeum	Klobor Cataumsulfathe&enestrich	Tronntolio	I ruscraatioammang	Rippperdacke	Minutatwolio Glastroc F	Panel Heizungdecke MCI	Fußboden WC Fkir	Fließen Kushar	Abdichtung	Calrburnsulfatfhe&enestrich Troomfolia	TSD (Isover)	Rippendecke Mineratwolfa	Minerauwone Baterioc F
Zuordnung bzw. Lage			NUT NUT TOU				WC			Anshich + Putz		Anstrich		Metallerkleidung	Klassenräume, Vvorraum	M USER			Neues Mauerwerk & Beton		Klasseritiuma								Flure, Tropponhalio Wost								WC Flur						
aufelbezeichnung auf Bautelikatalog)			M mild meters	and the transferrer to the An																	5 04 Eußtweiten	lassenraume							5.03 Flure, rennenhate West								4 5.02 Fußboden WC lur						
Bauteligruppe B Name (1			A A A A A A A A A A A A A A A A A A A	and and and an event			nnonausbau			nenausbeu		nnenausbeu		neusben	pusament				putwoou		lecter 1 0G-2 0G H	×							Jecken 1.0G-2.0G H								Decken 1.0G-2.0G						
Bautell-KG	335	331	336	335	335 331	900	1 I	CHr	342		345	JI III	341	-	341		342	342	-	341	341		362	362	362	361	364	423	5	352	352 352	352	352	351	363	423		362 363	352	362	362	351	363
Bauteligruppe_K G	330	18	330	330	330	330	340	040	340	340	340	340	340	340	340 340		340	340	340	340	340		350	350	350	350	350	350	350	350	350	350	350	350	350	423	350	350	350	350	350	350	350

Pe_K Bautell-KG	Bauteligruppe Name	Baufellbezekhnung (aut Bauteiketalog)	Zuordnung baw. Lage	Bauferid Schröttboordmung	Schichteolog (m) = m/m*	Menge enge Neu (m)	ALCA (Summar	and the second s	Kommentar / Aumerkung
363				CKBI	0,0125	7.4 G	PSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool		
	Decken 1 0G-2 0C	3 H 5.01 Fußboden WC M / W West	WC M / W West, Putzraum	Fußboden WC		27,6	(any)	3.6 Bodenaufbauten; 1A_210950G2_A; 3.10 Details: 1A_22680_0	
352				Fleßen	0,01	27,6	Steinzeugfliesen glastert (de)		
362				Kieber	0,003	27.6	Fliesenkieber (de) en		
352				Abdiciniting	0,001	21,6	Pre-reoppentate zur Abdichtung (de) Coloisen Materiale (46)		
202				Cadauttsuitainesteriestikan	0,045	27.6	DE-Monnenfalestrat (08)		
362				TSD (Isover)	0,012	27.6	Mineralwolle (Boden-Därrmung) (de)		
351				Ruppondocke	0,33	27,6			
363				Mineralwole	0,05	27.6	Mineralwolle (Fassaden-Dammung) (de)		
363				Glasroc F	0,015	27,6 GI	IPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (do)		
363				GKBI	0,0125	27.6 GI	PSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (de)		
	Dech	Bautellaufbaut Dach EPS 031	Dach Ausrichtung Sud	Dech Sud			/ sea	Grundriss: 1A_21005002_R, Schnitt. BB- CG, Desals Dech: 1A_22601_F; Schichtaufbau IBF	
442				PV-Anlage		E	hotovoltaiksystem 1000 kWhim2*a ohne Stromgutschrift	1A_21304LP4_B	325 Module, 84,5 kWp
363				Dachabdichtungsteahn Polyotetin	0,01	613,3	(00) TPO/FPO Dach-und Dichtungsbahn (de)		
363				neoTopDach EPS 031	0,3	613,3	EPS-Hartschaum (Rohdlichte 15 kg/m²)		
361				Damptsporte Remv. Decke	0,0025	613,3	Dampfbremse PL (do)		
364				Gpskartonplatte	0,02	613,3 GI	IPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool		
364				Mineralwola	0.05	301.8	Minestwole (Boden-Ditmoning) (de)	1A 210750G2 F	
3054				Glastoc I	0,015	391,8	Gipsbeuptatte (Feuerschulz, 12,5mm)	1A_210750G2_F	
364				Akusikdecke	0,02	391,8	Nicht dargestellt. Kein Datensalz vorhanden	1A_210750G2_F	
423				Panool Hoizdocko Rohau	0,02	149,2	Extern über Sockelbetrag QNG	1A_210750G2_F	
423	Davis	Raidala Davit Davh	Dach Austrichtung Mort	Paneer Heizdecke McJ	0,02	1.66	EXIEM UDBL SOCKEIDEILEG GING	Geneties 1A 21005062 B Schult GG.	
	10000	EPS 031						GG, Detark Dech. 1A_22601_E, Schichteufbeu IBF	
363				Dachabdichtungsbahn Polyoletin neoTor/heith FDS 031	0,0025	200.6	FPO/FPO Dach-und Dichtungsbahn (do) FPS-Hartscheum (Roholichte 15 kolm?)		
363				Dampfsperre	0,0025	280,6	Dampfbremse PE (de)		
361				Remy-Decke Checkerthonaldte	0,2	290,6	DSDI ATTE NACH DIN EN 52011ND DIN 181807Tcm		
					20,02	0.000			
364				Mineralwole Glastor [0,05	196.7	Minershwolle (Boden-Dammung) (de) Gesteunsette if euerschutz 12 Smm)	1A 210/5062 F	
364				Akusakdocke	0,02	196,7	Nicht dargestelt. Kein Datensatz vorhanden	1A_21075062_F	
423				Panoel Heizdecke Rehau	0,02	10,6	Extern uber Sockelbetrag QNG	1A_210750G2_F	
423				Panool Holzdocke MCI	0,02	96,2	Extern über Sockelbetrag QNG	1A_210/50G2_F	
	Aussonwände	AW Tropponhaus EPS	Aussonwand - TRH - Wost	Aussonwand Nord - Rogotassado - Tropponhaus Wost				IBP Sanorung Uhlandschulo,	
335		LUIC		Kuntahantzputz	0,01	38,1	Kunstharzputz (do) en de	19771100007 0.0MM (MIRANDON DOCIDIO	
335				Warmedammung Hart Neu	0,3	38,1	EPS-Hartschaum (grau, Roholichio 20 bis 25 kg/m²)	c c	Constraints of March 10 Constraints
3				Mauer werk	c'n		Mauczziczica (ungerunit) (gc)	D	erecmung wauewerk reau in upersion. Flischen Volumen neu
336				Putz	0,01	38,1	Gipspulz (nnen) (de)		
336	Arreconwanda	AW mit I netrate	Arssenwand - TDH - West	Anstroch Aussenwend Tvn VID - TDH	0,0025	1.8	Innerfarbe Dispersionsfarbe scheuerfest (de)		
335				Kuntzharzputz	0,015	17,8	Kunstharzputz (de) en de		
335				Vakuumsandwichelement VIP/EPS	0'08	17,8	externes EPD- EPD-POR-20200138-IBC1-DE		
331				Mauenwork	0,3		Mauerziegel (ungefulit) (de)		erechnung Mauerwerk Neu in Ubersicht Flächen Volumen neu
336				Putzmörtol	0,01	17,8	Gipsputz (innen) (de)		
	Aussenwände	AW mit Isover	Ausserwand - TRH - Mitte	Aussonwand Typ Isover				Grundins: 1A. 21005052. R; Schnift 1A. 21016566 F; 1A. 210185181 F; Ansichten: 1A. 21021A0. G	
335				Isover Ultimate	0,2	47,3	Mineralwolle (Fassaden-Dammung)		
331				Mauerwerk	0,3		Mauorziogol (ungotütti) (do)	œ	erechnung Mauerwerk Neu in Übersicht Flachen Volumen neu
336				Putrmortel	0,01	47,3	Gipspulz (mnen) (do)		
	Aussenwande	AW Treppenhaus MW Putz	Ausserwand - TRH - Mitle	Aussenwand Typ Steinwole				Grundriss: 14_21005062_R; Schnitt 1A_210168G0_F; 1A_21018SHH_F; Ansichten: 1A_21021A0_G	
335				Kunsthartzputz	0,015	57,0	Kunstherzputz (de) en de		
335				WDVS Storwollo Mauenwerk	0,3	57,0	Minembrolle (Fassaden-L)Immung) (de) Mauerziedel (ungefult) (de)	a	erechnung Mauerwerk Neu in Übersicht
200					÷		Sound Sciences in the same state of the same		Flachen Volumen neu
000				Dutrocktol	0.04	02.	Circuite Circuit 24-1		

Maximilian Schleicher

Kommutul / Amerikang			Gesam Stahlbeton Neu Außerwände Berechnung siehe Tabolie: Übersicht- Hischen Volumon Neu				Gesami Stahlbeton Neu Aufkerwände. Berechnung siehe Tabelle. Übersicht- Flachen Volumen Neu									Beleciniung weuerwerk veu in ubersicht Flachen Volumen neu				Berechnung Mauerwerk Neu in Übersicht	Flächen Volumen neu			Berechnung Mauerwerk Neu in Übersicht	Flachen Volumen neu			Berechnung Mauerwerk Neu in Übersicht				Gesant Stahtbaltm Neu Außerwande. Berechnung siehe Tabelle. Übersicht- Flachen Volumen Neu				Gesamt Stahlbeton Neu Autkerwände. Berechnung siehe Tabolie: Übersicht Flächen Volumen Neu		
Cuelling International Cuelling International Counternations versions runt statestatester Planer mit Vessangen etc. ablegan)	Grundriss: 1A_21005002_R, Schnitt: 1A_21016SGG_F; 1A_21018SHH_F; Ansichten: 1A_21021A0_G				Grundits: 1A. 21005063 R; Schnitt 1A. 21016566 F; 1A. 210185HH F; Ansichten: 1A. 21021A0 G			3.6 Bodenaufbauten; 1A_210950G2_A; 3.10 Dvalie: 1A_2280.0	October 117 22000 0				Grundriss. 1A_210040/G1-1_KSchnitt.	1A 21014SEE G				Grundriss: 1A_210040061-1_KSchnitt: 4A_240445EE_C				Gundriss: 1A_211040G1.1_0; Schnitt 4A_340486225_5_4A_340485144_5	Ansichten, 1A, 21021AO G			Caundriss 14_21104061-1_0; Schnitt 14_210168666_F; 14_21018SHH_F; Ansichten: 1A_21021A0_G				Gundres: 1A_21004OG1-1 K, Schrift 1A_21016SG0_E, 1A_21018SHH_F, Ansichen: 1A_2102H0_G, Broschure Dammert			Canadess 1A 210040051-1 K: Schufft	Anschlon, 1A, 21021AO, 6, Broschline Anschlon, 1A, 21021AO, 6, Broschline Dammart				3.6 Bodenaufbauten, 1A_210940G1-1_A, 3.10 Details, 1A_22680_0
al CA Datement		Kunstherzputz (do) en de	LF 9-1 lattice laws, the second se	Gipsputz (ennen) (de)		Kunstherzputz (de) en de Atoonstructis (Loconstant Disconstant) (de)	Transportbeton C25/30 (de); Bewehrungsstahl (de) en de	Gipspulz (nnen) (de)	.1	(m):	Mineralwolle (Fassaden-Dammung) (de)	GIPSPLATTE NACH DIN EN 520 UND DIN 181807 Tool (de		Kunstharzputz (de) en de	EPS-Hartscheum (greu, Rohdichte 20 bis 25 kg/m²)	MauerZieger (ungetuilt) (de)	Gipspulz (mnen) (de) Innenfartio Dispersionsfarbio scheuertest (de)		Kunstherzputz (de) en de	externes EPD: EPD-POR-20200138-IBC1-DE Mauserzhenel (uncefuth) (de)	(Cineratz (innen) (da)	fam) is some investories	A the south with a first south on the south of the south	Minorativodie (Flassadon-Dähmnung) Mauerziogor (ungoruiti) (de)	Gipspulz (eneen) (de)		Kunstherzputz (de) en de Minerskedie (Eessaden J)emminn) (de)	Mauerziegel (ungefullt) (de)	Gipsputz (innen) (de)		Kunstharzputz (de) en de EBS Hartechaum (orau: Biobuchto 20 his 25 boliezh	Transportbeton (255/30 (de); Bewehrungsstahl (de) en de	Gipspulz (mnen) (de)		Kunstherzputz (de) en de Minorokodio (Faccodon Dammuno) (do)	Transportbeton C25/30 (de) Bewehrungsstahl (de) en de	Gipsputz (innen) (de)	
nn Minge Inn J Menge Neu Inn J		5 11,3	2	11,3		40		4.0 84,1	84.1	84,1	84,1 84,1	5 84,1		38,8	38,8		38,8		5 16,4	16,4	18.4	£00	0.00	30,6	30,6		29,2	al ave	29,2		14.7		14,7		53		5.3	87,8
		0,015	50	0,01		0.015	0,3	0'0	0.04	0,05	0,33	0,015	_	0.01	0.3	5'0	0,01	7441	0,015	0,00	100	00		0,3	0,01		0,01	0,3	0,01		0,015	0.3	0,01		0,015	0,3	0,01	
Bauini 4. Schlothteze chimug	Ausserwand TRH - Nord - EPS	Kunsthartzputz	Beton	Putzmörtol	Aussemmand TRH - Nord - Sternwolte	Kunsthartzputz Mrth.//s_shimmedia	Belon	Putzmortei Fußboden Treppenhalle 2.00	Kunststeinplatten	Mortelbelt	Fäppendecke Mineratwolle	Clastroc F	Aussenwand Nord - Regeitassade - Treppenhaus West	Kuntzhantzputz	Wärmodammung Hart Nou	Watewerk	Putr Anstricth	Aussemmend Typ VIP - TRH	Kuntzhartzputz	Vakuumsandwichelement VIP/EPS Mauewerk	Putravieto	Aussemmand Typ Isover	forward Blineter.	Issver Ultimate Mauerwerk	Putzmörtel	Aussenwand Typ Steinwode	Kunsthartzputz Wrtyvs: steewarlte	Mauerwerk	Putzmörtei	Ausserwand TRH - Nord - EPS	Kunsthertzputz EPS.031	Belon	Putrmontel Arreconsend TDH - Nord - Steinwolle		Kunsthartzputz WTR/V/S Startworlda	Beton	Putzmörtei	Fußboden Treppenhalle 1.06
Zuordnung bzw. Lage	Aussenwand - TRH - Mitte				Ausserwand - TRH - Mitte			Freppenhalia Mitte					Aussenwand - TRH - West					Aussenwand - TRH - West				Aussonwand TRH Mitte				Ausserwand - TRH - Mitte				Ausserwand - TRH - Mille			Ancerement TRH - Mitte				11 M M	Freppenhalle Mitte
Bauteilbezeichnung (laut Bauteilk atalog)	4							H 5.05 Treppenhalle 7	70100				AW Treppenhaus EPS	Putz				AW mit Lockplate /				AW mit Isover /				AW Treppenhaus MW Putz				~			,					H 4.07 Treppenhaus
Bauteligruppe Name	Ausserwande				Aussenwände			Decken 1 0G-2 0G					Aussenwände					Aussenwände				Aussenwände				Ausserwande				Aussenwände			Aree on willingin	2010 Back			00	Decken EG - 1.0G
Bautell-KG		335	331	336		335	331	336	362	352	364	354	2	335	335	125	336		335	335	UR	-	246	331	336		335	331	336		335	331	336		335	331	336	
Bauteilgruppe_K G	330	330	330	330	330	330	330	330 350	350	350	350	350	330	330	330	230	330	330	330	330	300	330	000	330	330	330	330	330	330	330	330	330	330	3	330	330	330	350

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Kommeritar / Annechung																					Gesamt Stahlbaton Neu Außerwande	Berechnung siehe Tabeller Übersicht- Flächen Volumen Mau							Gesamt Stahlbaton Neu Außernwarde	Berechnung slehe Tabelle: Übersicht- Flachen Volumen Neu						Gesamt Stahtbaton Neu Außerwande.	Berechnung siehe Tabelle: Übersicht- Flachen Volumen Neu						Berechnung Mauerwerk Neu in Übersicht	Flächen Volumen neu				Berechnung Mauerwerk Neu in Übersicht	Flachen Volumen neu		
Callen (July Kata Nile warenedien) Collenting Nile Serate Hange Pollene mit Messangen etz. zähigen)				(0)		3.6 Bodenaufbauten; 1A_210940G1-2_A; 3.40 Develer: 1A_22091_0	A 10 COMP. 14 COMP. A						3.6 Bodemarthauten 1A 21036FG2 (1:3.10	Details, 1A 22680 0										3.6 Bodenaufbauten, 1A_21093EG1_A, 3.10	Details, 1A 22680 0										Dotal Tropponhaus/Aufzug 1A_22554_E.pdf, Excell Tool Ubensicht Flächen Neu				(de) (de)	Grundriss: 1A_21003EG-1_S, Schnift 1A_21014SEE_G					Crundriss: 1A_21004001+1_KSchnitt:	A AURSEL G					Grundres: 1A. 210400G1-1, K; Schrift 1A. 210165G6 F; 1A. 210185HF F; Anschlen: 1A. 21021AD_G; Breschine Diamond
4.C.A.Daterroet	1	1	1	GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool (4	Extorn über Sockobetrag QNG		Linoleum (de)	Kieber für Gipsplatten (de)	Calciumsultatestinch (do)	Minesilwolle (Boden-Diamining (de)	I	Mineralwolle (Fassaden-Dammung) (de)	CHORLATTE RACH DIVER N220 UNU DIVERSION 1000 (0		Steinzeugfliesen glastert (de)	r reservation (au) en Calciuma illatactrich (da)	PE-Noppenfole zur Abdichtung (de)	externes EPD: EPD-POR-20200138-IBC1-DE	Mineralwolle (Boden Dämmung) (de)	Zementmontel (De)	Transportbeton C30/37 (de): Bewehrundsstahl (de))	-	1		Statization (station)	Fileserkeber (de) en	Calciumsulfatestrich (de)	PE-Noppenfole zur Abdichtung (de) Minseetwelle Riterten Dismenient (de)	Transportbeton C30/37 (de): Bewehrungssteht (de))		Mineralwolle (Fasseden-Dämmung) (de)	GIPSPLATTE NACH DIN EN 520 UND DIN 18180 / Tool	GIPSPLATTE NACH DIN EN \$20 UND DIN 18180 / Tool	GIPSPLATTE NACH DIN EN 520 UND DIN 18180		Transportbeton C30/37 (de), Bewehrungsstahl (de))		Mineralwolle (Boden-Darmung) (de)	oysiyroi mammistori (XPS) (de) Exitudienter Polysiyroi mem		Kunstharzputz (de) en de	externes EPD: EPD-POR 20200138-IBC1-DE Exteriordee Deliverant Disconstant (VDC)	Mauerziegel (ungefüllt) (de)	(Sinson 47 Januar) (de)	Jones January Street B. Street Control	Kunstherzputz (de) en de	EPS-Hartscheum (greu, Rohörchie 20 bis 25 kg/m ¹)	EXtrumenter Proysoynus userint terren (xxx xx) Mauerziegei (ungefulfi) (de)	Gipspulz (innen) (de)	Innertarbe Dispersionsfarbe scheuerfest (de)	
Menge (m2) (m3) (m3)	87,8	87,8	87,8	87.8	87,8	42,4	42,4	42,4	42,4	42.4	42,4	42,4	128.5	-	128.5	128.5	128.5	128.5	128,5	120.2	128.5		128,5	47,6	47.8	47,6	47,6	47.6	47.6		47,6	47,6	47,6	47.6		18,4		76.9	272		8.8	8,8	1100	88	22	20,1	20,1	001/2	20,1	20,1	
ichichidicke (m) = m/m*	0,04	0,05	0,33	0.015	0,03		0,003	0,002	0,015	0.012	0,33	0,05	GLOTO		0.01	0.045	0,001	0,028	0,012	0.01	0.12		0,05		0.04	0,003	0,045	0,001	0.29		0,12	0,027	0,027	0.04		0.2		0,2	ZL'n		0.015	60'0	0,3	0.01	1.010	0,01	0,3	0,3	0,01	0,0025	
Bautek ¹ Bchichtheze chnung	Kunststomplatten	Abrtelbett	lippendocko	anneramone Blastoc F	Jockenheizsystem	ußboden Trappenhalle 1:0G	indeum	(leber	Calziumsulfathie&enestrich	rentrices SD (Iscover)	dippendecke	dineralwolle	Jasfoc F Julthoden Transenhalte F.G		hesen Antonio	Vetore 2.al/aumsultattice8.enosthich	renntolie	/IP Akusbk EVP	(SD (Isover)	.ord/hisu solioich	-powerse cuertiquestese Stabilitation C30/37		Ges Austerbicht	ußboden Treppenhalle EG	tion of the second s	Geber	Calzumsulfathio8 enestrich	rennfolle SSD flewoort	ou (sorrer) Ramv (becke mit feitendeckund		dinerativole	3igps CD6027	ragproofil Rigps	Sospletten Tvp DFR	vultaug Milito	Seton		MV.	Gunuau appearance. I Gunuau ac	usserward Typ VIP - TRH	kundriantzputz	/akuumsandwicholemont VIP/EPS 2006/disementatio MID/VS	dauenwerk	3. it temperat	ustroven tussenwand Nord - Regelfassade - Treppenhaus West	suntahantaputa	Natimedammung Hart Neu	Succession vice of a contract of the contract	Zin	Visitich	ussommand TRH - Nord - EPS
Zuordnung ban. Lage	-	~				reppenhalle Ost				_			Res (Ost) 089 (Millio)	ropponhallo				-						180 Treppenhale West											vufzug Mitte					Ussonwand - THH - West /					ussenwand - TRH - West	-			-		ussonwand - TRH - Mitte
Baufallissaschnung (laut Bautelik etalog)						H 4 06 Treppenhaus	10/0						H 3 OB Fußboden	gegen Erdreich										H 3.03 Fußboden 0	unterkellert - TH										MW & Beton Neu /					AW mit Lockplate					AW Treppenhaus EPS	2014					
Bauteilgruppe Namo						Decken EG-1 0G							Decken LIG - F.G	2										Decken UG - EG											Innonwände					Aussenwände					Ausserwande						Aussenwände
Bautell KG	362	352	301	363	363		362	352	352	162	361	353	000		352	162	162	362	362	202	161		163		630	162	362	352	191		363	363	192	163		111		341	242		335	335	101	13R		335	335	131	36	336	
BauteligruppeK	350	350	350	350	350	350	350	350	350	350	350	350	250	}	350	350	350	350	350	300	350		350	350	- Che	350	350	350	350		350	350	350	360	340	340		340	Treppenhaus EG-UG	330	330	330	330	uce.	330	330	330	330	330	330	330

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Bauteligruppe _. G	K Bautell-KG	Bauteligruppe Name	Bautellbezeichnung (auf Bauteikatalog)	Zuordnung bzw. Lage	Bautrei-/ Schröttlezerochnung	Schichtrische Menge [m] = m'm' (m2) Menge Na	el C.A.Datemet	Guildin gine and se versionen Guildin gine and se versioner Plans net Mexanger etc. Biogen) Plans net Mexanger etc. Biogen)
330	335				Kunsthertzputz	0,015 14,4	Kunstharzputz (do) en de FPS-Hartechaum (reau, Biobishte 20 bis 25 koled)	
330	335				Socketdammplatte WDVS	0,2 4,955	Extrudiator Polystyrol Dämmstoff (XPS)	
330	331				Belon	0,3	Transportbeton C25/30 (de), Bewehrungsstehl (de) en de	Gesant Schlebun Hab Aufserwande, Berechnung siner Tatelle. Uberschl- Flazher Volumen Nau
330	336	Arrest environmental	A M and Louise	Areconnect TDL Mitte	Putrmörtel Autocommed Tim Jourse	0,01 14.4	Gipspulz (mnen) (de)	Cauchines 4A, 24404004 4, 0: Cohode
2		AUSS 67 MOTION	AVY THE ISOUCH	ANNA - TRAT - DRAWTERSON	savosi då i puswussenv			Automas, IA, Z. 100-24-12, Semin, IA, 21016560, F. M. 2103BHLF, Anschen, TA, 21021AO G
330	335				Isover Ultimate	0,2 14,464	Mineralwolle (Fassaden-Dammung)	
330	331				Addressed with the second seco	0,3	Rauerzegel (ungefult) (de)	Berechnung Mauerwerk Neu in Ubersicht
330	336				Putzmortel	0.01 17.366	Giosputz (innen) (de)	Flaction Volumen neu
330		Aussenwände	AW Treppenhaus MW Putz	Aussenwand - TRH - Mitle	Aussenwand Typ Steinwole			Geundriss, IA_21104OG1-1.0, Schruft IA_20105G5/F_1A_20105HH_F; Ansidam, IA_21021A0_G
330	335				Kunsthattputz	0,015 11,1	Kunstharzputz (do) en do	
330	335				VIUVS Sterrworte Sockeldsimmplatte WDVS	0,2 5,148	Extrudienter Polystyrol Dämmstoff (XPS)	
330	331				Mauerwerk	0,3	Mauerziegei (ungefull) (de)	Berechnung Mauerwerk Neu in Übersicht FBichen Volumen neu
330	336				Putzmörtei	0,01 14,2	Gipsputz (mnen) (de)	
Sonderpositione		Jach		Allika Ausrichtung Süd	Attika Süd in Volumen Anooption	Menae Neu		Grundnss: 1A. 210040051-2. H: Schnitt: AA.
						Lui		HH, Dotal Dach 1A 22601 E
300	364				SOCKeIPULZ (Spritzwessserbereach)	0,015 0,448	Mineralwolle (l'assadon-Dâmmung) (de)	
360	364				OSB Platien	3,284	Spanplatta (generisch) (de	
380	364				MW-Dännung EPS 031	5,50%	 Mineralwolio (Fassadon-Dämmung) (do) EPS-Hartscheum (Robolichte 15 kohr) 	
360	361				Kantholz	0.31	8 Konstruktionsvolthoiz (Durchschnitt DE)	
360	364	Tauch		Alther Associations Mand	Authoch Attikes Reset in Volumenn Ammendeum	0,115	Aluminiumbioch (do)	Grandeire 1A 24000021.3 N. Schoolt AA
8		1000		DIGN FAIRWICHERS SAME		Luij		HH, Detail Dach 1A, 22604 B
360	364				Sockelputz (Spritzwesserbereich) WDVS	0.015 0.856	Kunstharzputz (do) on do Minerekkode (Fessesten-Diamenund) (de)	
360	364				OSB Platter	1,670	Spanplatte (generisch) (de	
360	364				MW-Dammung	1,990	Mineralwolle (Fassaden-Dammung) (de)	
360	361				Kantholz	0,320	EL7S-HartScheum (Kondiche 15 Kgm?) Konstruktionsvolholz (Durchschnitt DE)	
360	364				Auttech	0,160	3 Auminiumblech (de)	
360	-	Dach		Pultirist Ausrichtung Nord	Putritist Nord in Volumen Angegeben	Menge Neu Im7		Grundriss: 1A. 21004061-2. N; Schnitt, AA, HH; Dotait Dach 1A. 22602 B
360	364				Sockelpultz (Spritzweisserbereich)	0,015 0,745	Kunstharzputz (de) en de	
360	364				WUVS OSB Plattern	9//8	Minteramotie (rassaden-Liammung) (de) Snammatia (namariach) (da.	
360	364				MVV-Dämmung	0,88/	Minoralwolio (Fassadon-Dămmung) (do)	
360	364				EPS 031	1,115	EPS-Hartscheum (Rohdichle 15 kg/m ⁹)	
360	-	Dech		Attika Anbau Ausrichtung	Attika Sud in Volumen Angegeben	Manga Nau		Grundriss: 1A_21004OG1-2_N, Schnitt. AA,
260	36.4			Sud	Confidence de (Creditment softworkich)	0 010 0 100	IC anothese such of an dis	HH, Detail Dach 1A 22601 E
360	364				MDVS	0,786	Mineralwolle (Fassaden Dämmung) (de)	
360	364				OSB Platten	1,430	Spanplatte (generisch) (de	
360	364				MW-Datemung	300'S	Mineralwolle (Fassader)-Dammung) (de) F EPS-Hartscheum (Rohdichte 15 kohr?)	
360	361				Kantholz	0,130	Konstruktionsvolhoiz (Durchschnitt DE)	
300	364	Teach		Allen Anhous Associations	Attite Med in Volumon & nearther	0,050 Allencer Alers	Akuminitumblech (de)	Crusteiner 14: 21004/001-0-11: Catriati: 24
2000		10.000		Nord	manufacture encourance of the second s	[m]		HH, Detail Dach 1A 27604 B
360	364 364				Sockelputz (Spritzwasserbereich) WUVS	0,015 0,346	Kumstherzputz (de) en de Minerekvolle (Fesseden-Dammund) (de)	
360	364				OSB Platten	0,674	Spanplatte (generisch) (de	
360	364				MVV-Dämmung	0,800	Minoralwolio (Fassadon Dämmung) (do)	
360	364				EPS 031 Kanthož	0,335	EPS-Hartschaum (Kondichie 15 Kg/m ⁻) Konstniktionsvolibol7 (Durchschnill DF)	
360	364				Authech	0,066	Aluminiumblech (de)	
360		Dach		Pullfirst Anbau Ausrichtung	Putifirst Nord in Volumen Angegeben	Mongo Neu		Grundriss. 1A_210040051-2_N, Schnitt. AA, ULP. Schrift Davier 1A, 258005_B
360	364			DION	Sockelputz (Spritzwas serbereich)	0,015 0,338	3 Kunstherzputz (do) on do	HIT, Detail Details in 22002 0
360	364				WDVS	4,44	Mineralwolle (Fassaden-Dammung) (de)	
360	364				OSB Patten MW-Dättenung	0,400	Spenglatte (generacity) (de Mineralwolle (Fassaden-Dänmung) (de)	

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Kommenter / Aumerkung	
Collard (Inter all as a version) Collard (Inter all as a version) Columnity version (Inter all all agen) Place unit Messungur etc. shingen)	
ALCA Datamet	EPS-Hartschaum (Roholichte 15 kolm ⁵)
Menge Menge Nau [m-]	0.507
Baumala Sahuchtboarchnung	EPS 031
Zuordnung bzw. Lage	
aufelle-sechnung lauf Baufelle (
Bauteligruppe E	
Bautell-KG	364
ellgruppe_K	

Igruppe_KG Baurel-KG	Beuteligruppe Name	Cetal Cotumentan Name	Zuerdrung ben Lage	Bautelly Schickbezeichnung	Herteller Produktione	-	Bodia Permise	Hithe Fennier FI	ache Gennel	Rums Downsets in sLCA
234	Fernitar - Nord	169 21.12 TH 50 Nord	Ferster TPH - Mits - Nov	Fendor TPH - Mille - Nord	SCHOOD II HIT AVIS 20 SI	-	521	2,635	12,11	Fereler EG 1991 - Mite - Nord - Tell 1 nicht offenber, Perster EG 1994 - Mite - Nord - Tell 2 zum offen
ā	Fendlar - Nord	162 ED Nerd Achies C-D 2 1, 15-6, 161 ED Nord Achies D-E 2 1, 15-4, 100 ED Nord Achies E-F 2 1, 15-3, 150 ED Nord Achies F-D 2 1, 15-2, 1560 ED Nord Achies 0-H 2 1, 15-1	Ferder Nord Adla C.H	Pender Nord Massentremer	School II mit AVS 20 SI	-	96'94	2.46	116.50	Parater EO Nord Rassenstmener Teil 1 Hoth Offices, Paneter EO Nord Kassenstmener Teil 2 aan Other;
100	Fender - Nord	138 2.1.16 80 TH View	Ferdels' TPH West	Perseter TPH West		-	22	1,75	3,82	Fension EG TPH West Tell 1 geschlosent, Fension EG TPH West Tell 2 zum
100	Femilier - Nord	167 Kpp EG Nord WC Actae A-B	Ferder WC West	Funder WC West	SCHOOD AWSADS SI	5	2.67	0,085	237	Fender WC View EO & LOD
R R S	Fendler - Stel	111 2 135 EO Sud teelles Werken	Ferder God A-B	Forster Vertion	Schoos II nit AWS 30.51	-	8.64	1,867	679	where EG 1 SOJ Werken Teil 1 nicht zum Others, Ferster EG 1 S2d Auferen Teil 2 nice Version Franken FC1 fond Massessmensen Teil 3 Moness
1.23	Fender - Stel	Kain Detail Vorhandien, Nur Liefferschein	Fertaler AW Stud	Chertofter Sod		-	観楽	0.85	39,69	Control of a control of the control
2 2	Fendar - Okt	Nich Vohenden	Ferder TPH - MIRe - OK	Pensor TPH - Mile - Oil	SCHOOD II HIT AWS 90 SI	-	23	1,68	425	Fensive Trapperhaus Mills Austrictions Oet
10.10	Fendler - Nord Arbeu	1004 EC Nerd 21,11-1; 1564 EC Nerd 21,11-2; 1574 EC Nerd 21,11-3;	Ferater Nard Actin L-M	Frender Nord Massendminer	School II mit AWS 20 SI	-	26.25	1,965	62,90	Perster EC Arbs. Note Rasserdimmer Teil 1 richt director, Fenster EG 1 Sod Verten Teil 2 zum Offman (c.4.0003), Fenster EG Arbau Note
ă ă	Fentler - Ost Arbau	165a Okt EG Dreintensker WC	Fersier Oil Fessiole Artist	Fender Ofenber Out	SCHOOD II HIT AWS ID SI	-	1128	1095	125	Reservance Tell 3 Prove Linge Fender ED Drefressier VIC Ort
1	Fenster - Sod Antheu	Kein Detal Vorhanden, Nur Lieferschein	Ferder AV Std Arbeu	Cherichter Stud		-	27.8	0.68	25,72	Coefficit Stat EG Arbeu
M	1000									
NS N	Furstar - Nord	150b 21,18 1+200 Ferster Nord	Ferater Carg	Fender Oing			14	1,7	238	Fernier Carg Nord (EO-2.00)
ā	Ferster - Nord	138 2.1.17 1.00 TH West	Ferdam TPH West	Fertilier TPH West		ł	22	1,18	3.92	Feesler 1994 - Nord - West- Außerteit, Fenster 1994 - Nord - Viest- Mittele
22	Fensler - Nord	168 Kpp 1.00 Nord WC Actine A-B	Fertates' WC West	Fernition VAC Weak	SCHOOD AMSIADS SI	*	2.64	0,088	234	Fender WO Vest EO & LOG
834	Fundar - West	119 Kipp 1.00 west 049 Kipp west H 45 49, 048 Kipp west V 46 47	Perster Idasse 101 Kipp	Ferster Masse 101	SCHOOD AMSIADE SI	-	(335	9358	1,25	Pender Vesk Rop Rasemeum 101
ăă i	Fernitar - Stat	109 2 1.35 Heupigebruch 1.03	Ferder Klasse 101; 103- 107	Foreitor nel IV	SCHOOD TIME AVE SO ST	æ	9867	206	16,03	Fender OG 1 804 Fender Nasse für 102-107 Tel Nich oftenber, Fender OG 1 804 Fender Nasse für 102-107 Tel Olienber
204	Fension - Stud	110 2.1.39 Haupigebillude Leftmethel 1.00	Ferder Lehrnibel 102	Fernitist mit PV	SCHOOD II INLAWS SO SI	-	4.205	2.08	8,66	Fendler OG 1 535 Fendler Lefensbel 102 Tel Noti Offenber, Fendler OG
24	Fensier-Ok	Nick Vohenden	Ferder TPH - Mits - OW	Femaler TPH - Mile - Okt	SCHOOD 11 mit AWS 30 SI	-	23	1,68	432	Parawa Lannasa Naci na chartar Parawa Trappertesa Mite Austricharg Ort
234	Fendler - Nard	15k 2.1.15 TH edds	Ferater TPH - Mite - Nox	Fension TPH - Mille - Nord	SCHOOD II HIT AWS 20 SI	-	621	1,75	9,12	renster 1984 - Nord - Mits - Außenteit, Fennter 1994 - Nord - Mite - Mitsels
100	Fendler - Nord Arbeu	153 2.1.15 1.00 Fender Nord Arbeit Oit	Fender Cang	Family Cang			14	1.7	238	Feeder Garg Nord (EG-2.00)
ĀĀ	Fender - Std Anteu	104 2.1.40 Nationgatioude Tropechaus	Ferotor Arbau TPH	Parados mái PV	SCHOOD II INT AVS 40 SI	-	3.95	1,742	6,85	Fersiter CO 1 S24 Notengebaude Trepombaus Tel Nicht offerbar, Fersit
A A	Fender - Stid Antheu	104 2 1.40 Nationgetieudie Theppenhaue	Fender Arbeu	Persons mit PV	SCHOOD II IN ANY SHOP	-	8.965	1742	15,62	Fension CO 1 Std Action Liberational supportances for Action Fension
234										
234	Fender - Nord	142a Oberadri Anteu Nord 2 1.27	Ferster Nord Oberlicht Arbeit	Clearant - Lattungagerat	SCHOOD II INT AVIS 20 SI	•	2.266	0.79	1,76	Oberlichter 1.00 Anteu Offen
224 234	Fendar - Nord	wide Voltanden - Grandage Plane und Schrifte	Ferster Nord Coefficit Arbeiu	Cherticht Creschosen	IS DO SAME THE IL COOLOG		327	a'ra	2.56	Contrainer 1.00 Arbou Ceschlossen
18th										
i a a	Femaler - Stud	107 2141b 200 Mask and EDV	Feraler Musik & EDV	Function and PV	SCHOOD II Init AWS 30 SI	**	8,995	1,742	15,67	Fension OG 2 Stad Vasherettung Cheerlehthysik Physik / Cherries Ted Math Offecture: Fension OG 2 Stad Vasherettung Cherrise/Physik Physik /
334	Femater - Stud	108 2 135 2 CO Nideniaum Musik	Fender Neberreum Musik	Females mit PV	SCHOOD II HIT AWS SO SI	÷	4,205	1,742	7,35	Fender OG 2 Stid Nebereum Musik Tel Offender, Fender OG 2 Stid Nebereum Musik Tel Monterber
<u>ăă</u> i	Fernitier - Stud	105 2 1.42 2.00 Voltemburg Physik	Ferder Votenstung Physik	Forstor nel PV	15 00 SAVE THE TWO ROOMS	-	3.995	1742	15,67	Fension CO2 Stat Vanteenburg Chemise/Payak, Physik / Chemise Tel Mch Offecter, Fension CO2 2 Stat Vanteenburg Chemise/Physik Physik /
201	Femilier - Stat	1004 2 1.41 2 CG Physik and Chereie	Ferder Chercellingsk	Fembler mit PV	SCHOOD II HIT AVIS 50 SI	*	3,995	1,742	15,67	Creents Ted Otheren Ted Othertown Fransfer OG 2 Stid Verbenehung Chemis Physics / Chemise Ted Nath
101			A DATA DATA DATA DATA DATA DATA DATA DA			11.0		111010		offerbar, Fender OG 2 S2d Vorberetung Chemis/Physik Physik /

*	10	Ferster - Std	106 2 1.45 2.00 Volterehung Cherrie	Ferder Voterelling Overlin	Fundae mit PV	SCHOOD II HIT AWS 90 ST	1 8,995	1,742	15,67	Fender OC2 Sci Voctereitung Chemis/Prysik Physik / Chemis Tei Ndri Offerber: Fender OC2 Sci Voctereitung Chemis/Physik Physik /
340	1234		Real Concentration	And a second sec		No. of the second second second second	10 NOV	100	Conservation of the second	Cheristel offerbar
340	157	Fendler-Oil	Note Vohanden	Feraler TPH - MIto - Car	Fender TPH - Mills - Out	SCHOOD 11 HIT AWS 90.51	1 23	1,83	432	Fension Tropperhaus Mits Austritung Cet
340	334									
340	334	Fernater - Nord	134 2.1.15 TH millio	Ferder TPH - Mile - Non	Fenster TPH - Mitte - Nord	SCHOOD II HIT AWS TO ST	1 521	1,15	9,12	Fensier TRH - Nord - Mite - Außenkelt, Fensier TRH - Nord - Mite - Mitebel
340	234				THE REPORT OF TH	Automatical and a second second	1000	2010	2	
340	334	Fernater - Nord	132b 2.1.18 1+20G Fensler Nord	Fersker Carg	Femater Oang		1 14	1.7	2,36	Fundar Carg Nord (EO-2.00)
340	334									
340	334	Fernater - Nord	15/21.162.00 TH West	Ferster TPH West	Femater TPH West		1 22	1,75	3,90	Ferster TRH - Nord - West-Außenheit, Ferster TRH - Nord - Viest- Mitabel
340	234								Service of	
340	834	Fernster - Nord	165 Kpp 2.00 Nord WC Achie A-B	Ferder WC	Fender WC				-02	Fension WC West 2:00
340	204								2	
Fension 2.00 cba	tictriar									
9%	234	Fension - Nord	145 Openidin Hauption Nord 2.1.25	Ferder Nord Obericht Arbeu	Obericht - Loftungsgerft	SCHOOD II INT AVS 20.51	8 3,238	0,845	274	Obsticiture 2.0G Offen
340	224									
340	234	Fendar - Nord	1500 Oberschi Hauptheu Nord 2.1.311	Ferder Nord Ceetickt Arbeu	Cleaticht Geschlossen	SCHOOD II HIT AWS 20.51	14 2.069	0,845	242	OberEchter 2.00 Geschlossen
340	234									

Appendix

AOJe ni steanete0		Innentüren Holz 88,5 (Innenfarbe Dispensionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Innentüren Holz 101 (Innenfarbe Dispensionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispensionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Hoiz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Innentüren Holz 101 (Innenfarbe Dispensionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispensionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispensionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (gererisch))
Klemmschuts ganze Höhe: BS = Bandseite BGS = Bandgegenseite										
Türobetili şichen		Resopal 9417-60	Resopal 9417-60	Resopal 9417-60	Resopal 9417-60	Resopal 9417-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60
Drückergarnitur außen D-Drücker, К+йлый, S=306аалде, Н+Hebel, М=Мизсhel, 8р=80дейди#		à	Kn B	Dr	Dr	Dr.	Dr	Kn B	Dr 2	à
Drückergarnitur in nen Drückergarnitur in nen D-Dröckr, M-Muschel, 89=80gelgriff H-Hobel, M-Muschel, 89=80gelgriff		ă	D	ā	ā	ä	ā	ā	Dr 2	ă
Schallschutz Rw'R (eingebauter Zust		°	•	-		-	0	33	33	•
bristra presidente pre		•	0	0	0	0	0	0	0	0
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Türaufschlagrichtung i=Innen, a=Außen			8		-		9	8		8
Zarg eno berfikische		RAL 9016	RAL 9016	RAL 9016	RAL 9016	RAL 9016	NCS S8000N	NCS S8000N	NCS S8000N	NCS S8000N
Коћраиńсћтаß Breite/Höhe (cm) Коћраиńсћтаß Breite/Höhe (cm)		88,5*213	101*213	101"213	101"213	88,5*213	101*213	101*213	101*213	101*213
BeirhornA'irias Div necharinka BeirhornA'irias		å	ü	ū	Re		Re			
neitischengeschneitigen Mersesernengeschlichtigt		L.	ш	L.	ш	u.				
Tuant Depution: Sch=Schebelür. T=Tele ekcylür F=Realing, R=Rodixy, S=Sektönelür, H=Rodix, Parlealing, R=Rodixy, S=Rodixy Adedarb2 ehcsäternöuderhcEA		٩	D	Q	Q	Q	Q	Q	Q	٥
Isin of the Migrid Part of the Isin of the Migrid Part of the Second Sec		Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Se Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55
Bitefentflödnü Richfant (Siener Siehen Siehe		H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf
Türp osition A=Russer, I=innen, F=Fassade/Fensterelement		_	L.	L.	L.	L	L.	L.	L.	_
8		073 WC Schüler	074 Putzraum	072 Vorraum WC	Vorraum WC 071 Schülerinnen	070 WC Schülerinnen	081 Flur	001.1 Textiles Werken	002 Hausmeisterraum	083 Flur
Seschold	Titel	9	EG	9	EG	9	9	9	9	9

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

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

Bauherr:

ete

Türliste

Projekt: Stand: 04.07.2016

Index:

Uhlandschule Brandschutz- und Objekttüren

Türtypen

i zlesnafeQ	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 113 (Innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))
BGS = Band Bnashind Brand									
tirober#åα	Resopal 10622-60								
Drückergar D=Drücker, K= H=Hebel, M=N	Kn A	Kn B	Kn B	Kn A	Kn A	۵ ا	Kn B	Dr.	ۍ ۲
Drückergar D=Drücker, K= H=Hebel, M=N	ă	ă	۵	۵	ŏ	ă	ă	ă	۵
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edonegasZ	NCS	NCS S8000N	NCS 88000N	NCS S8000N	NCS S8000N	NCS 88000N	NCS S8000N	NCS 88000N	NCS S8000N
Rohbaunich Skreeuw si	101*213	101*213	101*213	101*213	101*208	101*213	101*213	101*213	113,5*205
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egieztseuZ emueresen=M									
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	3 NR Textiles Werken	1 Bildende Kunst	2 Bildende Kunst	Nebenraum Bildende 5 Kunst	1 Nebenraum Brennraum	2 Nebenraum Brennraum	1 M.fkt. Fachunterricht	.2 M.fkt. Fachunterricht	 Lehrküche/Theorie
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	etiesnegegbnisä = 208	
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	H=Hebel, M=Muschel, Bg=Bügelgriff	
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i urg port	Тйрозйјол Ремывел, Ретонс, РF. авзадо/Fenslerelement Пробата Балански, РF. Базадо/Fenslerelement Прибата балаки си Канки и Сак, Басандра (П Бесбандо (Сакласки Канки Канки Сак, Басандра (П Бесбандо (Сакласки Канки Канки Сак, Басандра (П Басбандо (Сак, Ганевски Санки Сак, Ганевски Сак, Панита Сак, Басанда (Панита Басандо (Сак, Ганевски Санки Сак, Ганевски Сак, П Пипона Сак, Басак, Басандок, Ганевски Сак, Нанфок, Панита Басандо (Сак, Ганевски Санки Сакандо (Сак)) Пипона Саканда (П Саканда (
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AOJe ni steanete0	nnentüren Hotz 113 (Innenfarbe Dispersionsfarbe scheuerfiest (de); Spanplatte cenerisch) (dei)	nnentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	nnentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch))	mentüren Holz 101 (innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch))	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentúren Holz 86,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 88,5 (innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 88,5 (innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))
Klemmschult ganze Höhe: BS = Bandseite BCS = Bandgegenseite									
Türoberhilden	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60	Resopal 9417-60	Resopal 10622-60	Resopal 10622-60	Resopal 9417-60
Drůckergamitur außen D=Drücker, K=Knauf, S=Stotstange, H=Hebel, M=Muschel, Bg=80getgriff	Kn A	Kn A	۵	à	Kn A	۲ ۲	Kn B	Kn B	ă
Drůckergamitur in nen D=Dröcker, K=Kneu, S=Stotatange, H=Hebel, M=Muschel, Bg=80getgrtff	č	ä	ă	ä	Dr	Dr	Dr	Dr	ä
Schallschutz Rw'R (eingebauter Zusta	8	33	32	32	32	0	0	0	•
bnetanieneboß		•	°	0	0	0	0	0	°
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Bodenaufbau, Innen (cm)	ç	0 1	ę	0±	0±	±0	±0	0 1	0 1
Türaufschlagrichtung i≡Innen, a≡Außen				a.	9		e	8	
Sargenoberliäche	NCS	NCS	NCS	NCS S8000N	NCS S8000N	RAL 9016	NCS S8000N	NCS S8000N	RAL 9016
Rohbaurichtmaß Breite/Höhe (cm) Rohbaurichtmaß Breite/Höhe (cm)	113.5*206	113,5*205	101*213	101*213	113*205	88,5*213	88,5*205	88,5*205	88,5*213
gelrbanA\/ritesnewerine aniharban via	2		å	5	ß	Re	5	Re	ß
Zu satze ige nacharthen N=nseramgeeignet, F=feuchtraumgeeignet N=						L.	L.	u.	u.
Ťűranť D = Drehnůr, Sch=Schlebet ür, T = Teleakropůr F = Fantur, R=Rothor, S=Seldonadůr, ht=hubtor, F = Fantur Reisemont – Presidenting Adha – Automatiache Schlebedůr		0	0	٥	D	D	D	D	٩
Sargen Ngy Matika Su-Stahumkasungas., Se≈Stahledxs., So-Stahlwicksks, Narekala banna Berefalantskods. Hur-Houstandasungss. Hrt-Holtantantskonsarge	Su S040*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55
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Tinprégrip A=Auseer, l= inner, F=F assade/F ensier element	-			_		L.	-	-	_'
18A	Nebenraum Lehrküche	1 Technik/Werken	2 Technik/Werken	Maschinenraum	Technik/Werken	WC Lehrer	Vorraum WC Lehrer	Vorraum WC Lehrerinnen	WC Lehrerinnen
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ຽດປວຂອງ	g	g	g	g	9	9	9	9	g

Türtypen

AጋJe ni stesnete0	Imentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Imentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	imentüren Holz 101 (Innenfarbe Dispensionsfarbe scheuerfest (de); Spanplatte (generisch))	imentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	imentüren Holz 101 (Innenfarbe Dispensionsfarbe scheuerfest (de); Spanplatte (generisch))	Imentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Imentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Imentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	imentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))
Klemmschutzganze Höhe: BS = Bandseile BCS = Bandgegenseite									
Türoberflächen	Resopal 10622-60	Resopal 9417-60	Resopal 9417-60	Resopal 9417-60	Resopal 9417-60	Resopal 9417-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60
Drückergarnitur außen D=Drücker, K=ignaut, S=Sicsaange, H+H+bel, M=Muschel, Bg=Bicgelgrift	Kn B	Dr	Kn B	Kn B	ă	Kn B	۵	Dr 2	۵
Drückergarnitur innen D-Drückergarnitur (3=3osaange, H=Hebel M=Muschel 8g=8ogelgrift	ă	Dr	ų	Ŀ	ä	ă	ä	Dr 2	à
Schallschutz RWR (eingebauter Zustar	0	0	0	0	•	•	•	8	8
bristenieneboß	0	0	0	0	•	•	•	•	•
(wc) yearne 'nearneueog	9	9	9	9	9	9	9	9	9
(up) ueuu 'negneuepog	9	9	9	9	9	9	9	9	9
nsunA=6,nsen									
Buninoingelhosiulaiu	en .		8		0	69	69		
Zargenoberfläche	NCS S8000N	RAL 9016	RAL 9016	RAL 9016	RAL 9016	RAL 9016	NCS	NCS S8000N	NCS S8000N
оквенк зых Корранисритеß Breite/Höhe (cm)	88.5*170	88,5*213	101*213	101*213	101*213	101*213	113,5"213	113,5*213	113,5*213
DIN MCM241448		Re	ü						ß
Zusatzeigenscheiden M=massiaumgreignet, F=feuchtraumgreignet M=mgreignet, F=feuchtraumgreignet		ш	L.	L.					
Tühari Türki, Sch=Schebetkr, T=ekeropetri F=Felgitor, R=Rotior, S=Sekitoratior, H=Hotor, Pachador, R=Rotior, S=Sekitoration Achadade Schebetki	0	٥	٥	٥	_	-		0	0
Zargentyp/Matierial Su-Stahtum featungsz, Se=Stahteckz, Se-Stahtum featungsz, Se=Stahteckz, Se-Stahtum kickz, Hu-Houstantingsz, He-Hotz anger, Kurkantestoffahmen, Tu-Turnhalenzarge	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55
Türbini Parkani Bakan 1994 Onthe Satahan Karki Mi-Minak Rahaman (Baka G-Gak S=341 Hapi-Harini Gan, Gakan Bakan 1994 Danami Minakatan (Haman Danaman Gas	H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf
Türp osition A=Aussen, I=innen, F=F assade/Fensteretenen	_	-	_		_	_	_	_	_
16A	9 Putzraum	13 WC Lehrer	14 WC Lehrerinnen	2 Vorraum WC Lehrer	1 WC Behinderten	0 Putzraum	H Fur	1.1 Klasse	1.2 Klasse
	0	17	17	17	4	4	9	é	6
getog	EG	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06

Türtypen

AOJe ni steanete0		mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	nnentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch))
Klemmschutzganze Höhe: BS = Bandseite BCS = Bandgegenseite										
nərbətinədorüT		Resopal 10622-60	Resopal 9417-60	Resopal 9417-60						
D=Drickergarmitur außen D=Dricker, K=Knaut, S=Sickange, H=Hebel, M=Mustrel, Bg=Bicgelgriff		Kn B	۵	Dr 2	Kn A	Kn A				
Drückergarnitur in nen D-Drücker, K-Hvard, S-Sköfatinge, H=H ebel, M=Muschel, Bg=Bogelgriff		à	ă	Dr 2	ā	ă				
Schallschutz Rw'R (eingebauter Zus		33	32	32	32	32	32	32	32	33
bnstanienebo 8		0	0	0	0	0	0	0	0	0
(mo) ne&ufbau, kundineneboß		±0	±0	01	0Ŧ	01	0Ŧ	±0	±0	0Ŧ
(mo) nen ni, jus d'us neboß		0 1	р Р	유	0Ŧ	유	0F	0Ŧ	±0	ę
Türaufschlegrichtung i≡Innen, a=Außen		e	a.						-	
Zargenoberfläche		NCS S8000N	NCS 8000N	NCS S8000N	NCS S8000N	NCS 88000N	NCS S8000N	NCS S8000N	RAL 9016	RAL 9016
Rohbaurichtmaß Breite/Höhe (cm) оккячык зыг		113,5*213	113,5*213	113,5*205	113,5*205	113,5*205	113,5*205	113,5*205	113,5*205	101*213
skillshon NG										
n efter neg te ste set en de la cher neg te ste set en de la cher neg en cher neg en cher et en cher et en cher N=nesenen en cher et en N=nesenen et en cher et										
Türart D=Drahon, Sch=Schlebedür, T=T ele akoption D=Drahon, R=Rollor, S=Schlebedür, S=Schlebedür, R=Rollor, Rellor, Rello		D	D	Q	D	Q	D	D	D	٥
ieihe the Mydyfne the Statie of the Statie		Su Sp40*55	Su Sp40*55							
Türklerferti Heives Gewähleriel Gedas, Sedarischer Koller, Gescherter Gedas, Sedarige Heiternet Gas Feuchnunge, Heiterstrateiter Feuchnunge		H_stumpf	H_stumpf							
Türp osition A-Ausser, I=înnen, F=Fassade/Fensterelement		L.	Ļ	ļ	L.	L.	ļ	Ļ	Ļ	-
4		102.1 Lehrmittel	102.2 Lehrmittel	103 Klasse	104 Klasse	105 Klasse	106 Klasse	107 Klasse	108.1 Lehrerzimmer	108.2 Lehrerzimmer
Joriase D	l	8	8	90	90	90	90	90	8	g

ietsu Z

Türtypen

Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Irmentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Innentüren Holz 101 (Innenfarbe Dispersionstarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))
Resopal 9417-60	Resopal 9417-60	Resopal 9417-60						
Kn A	Kn A	Dr	Dr 2	D	Kn A	Dr	Kn B	Dr
ă	ă	ā	Dr 2	ă	ă	ă	ă	ă
32	32	32	32	32	32	0	•	0
0	0	0	0	0	0	0	0	0
0±	10	±0	07	±0	±0	0Ŧ	0 1	10
ţ	0 1	±0	07	ŧ	±0	0 1	위	유
		į			8		ca	
RAL 9016	RAL 9016	RAL 9016						
101*213	101*213	101*213	101*213	101*213	101*205	88,5*213	101"213	101*213
	=		II.	g		ß		=
D	D	D	Q	D	D	q	٥	D
Su Sp40*55	Su Sp40*55	Su Sp40*55						
H_stumpf	H_stumpf	H_stumpf	jdwnţs [–] H	H_stumpf	H_stumpf	jdwnţs [–] H	H_stumpf	H_stumpf
-	L.	L.	L	L.	Ļ	L.	_	-
Besprechung Sanitätsraum	Stellvertreter	Stellvertreter / Sekretariat	Sekretariat	Sekretariat / Schulleiter	Lehrerzimmer	WC Schüler	Putzraum	Vorraum WC
109.1	110.1	110.2	111.1	111.2	113	273	274	272
1.06	1.06	1.06	90	1.06	1.06	2.06	2.06	2.06

Ebelegenetik kurskersenges. Tur-Turnbakerzuge Tur-Turnbakerzuge Tur-Turnbakerzuge Tur-Turnbakerzuge Tur-Turnbakerzuge Turnbakerzuge Aschrektonskowk Kurskowskiewerke Aschrektonskowk Kurskowskiewerke Aschrektonskowk Aschrektonskiewe Kurskowskiewerke Aschrektowskiewerke Aschrektowskiewerke Aschrektowskiewerke Aschrektowskiewerke Aschrektowskiewerke Aschrektowskiewerke Aschaltererktowskiewerke Aschaltererktowskiewerke Aschaltererktowskiewerke Astronol Erickerktowskiewerke Astreisterereisterickerktowskiewerke
 ВР= 68/азтина (Ки-46/алабояйся), такая шорах. Тип"Шплавашорах. Тип"Шплавашора. Тип"Шплавашора. Тип"Шплавашора. Тип"Шплавашора Транисьтвора Транисталь Собала Собала Собала Собала Собала Транисьта Собала <li< td=""></li<>
EP=Edebalations: Limburgets: Питиливнозора: Питиливнозора: Turnurhalenzagnen Ku-skundstondiahm en, Turnurhalenzage Turnurhalenzage Turnurhalenzage Deröndizis: Eh=Edebalation Asstructuratione Schebelsting Asstructuratione Schebelsting Deröndizis: Eh=Edebalationes Asstructuratione Schebelsting Deröndizis: Eh=Edebalatione TürlügelanzahlvAnachbelsting Prinderenzeges Deröndizis: Reinderändige Deröndizis: Reinderände Schabalation Deröndizis: Reinderände Bodenaufschlass Bodenaufschalt Deröndizis: Keiteruk Bodenaufschalt Dröndizis: Keiteruk Bodenaufschalt Bodenzafbau Bodenaufschalt Bodenaufschalt Bodenaufschalt
EP=Edebalations: Кы-Калайсайана өк. TurTurhalenzage TurTurhalenzage TurTurhalenzage TurTurhalenzage TurTurhalenzage Dendektoz kinektonatorabe Aschaktoran Kurskonatorabe Aschaktoran Kurskonatorabe Aschaktoran Kurskonatorabe Aschaktoran Kurskonatorabe Aschaktoran Kurskonatorabe Aschaktora Kurskonatorabe Aschaktoratorabe Aschaktoraktorabe Aschaktoratorabe Aschaktoratorabe Dendenzehleka Minterenundenspeignet Childber Aschaktora Din kortektie Aschaktora Bodenarbiska Din kortektie Bodenarbiska Bodeneinstarbiska
 Ве-ебизатион Ки-Килавойали ел. Пи-Тиглайский Килавойали ел. Ти-Тиглайский Килавойали ел. Тигли Килавойали ел. Тигли Килавойали ел. Пи-Тиглайски сърдавой Пили Килавойали ел. Пили Килавойали ел. Пили Килавойали ел. Пили Килавойали ел. Пили Килавойали сърдавой Воделагара Кили сърдавой Воделаитела Кили Сили Сили Воделаители Кили Сили Сили Воделаители Кили Сили Сили Воделаители Кили Сили Воделаители Кили Сили Сили Воделаители Сили Сили Воделаители Сили Сили Воделаители Кили Сили Сили Воделаители Сили Сили Воделаители Сили Сили Воделаители Сили Сили Сили Воделаители Сили Сили Воделаители Сили Сили Сили Воделаители Сили Сили Сили Водела Сили Сили Сили Сили Воделаители Сили Сили Воделаители Сили Сили Сили Воделаители Сили Сили Сили Воделаители Сили Сили Воделаители Сили Сили Сили Воделаители Сили Сили Сили Сили Воделаители Сили Сили Сили Воделаители Сили Сили Сили Воде
EP=Gebalaktors, Pi-Pikumikasungs. EP=Gebalaktors (Ku-Kunakokimakona) Tu-Turhaiersunge Tu-Turhaiersunge Asch-kulomaische Schiebelör, Asch-kulomaische Schiebelör, Asch-kulomaische Schiebelör Asch-kulomaische Schiebelör Verhassaumpeignel, F-dieuchranzengen Rohhaunichtmaß Breiter/Höhe (cm) Drückerganzum Innen Bodenaufbau, Innen Bodenaufbau, Innen Bodenaufbau, Innen Bodenaufbau, Innen Bodenaufbau, Innen Bodenaufbau, Innen Bodenaufbau, Außen (cm) Bodenaufbau, Innen Bodenaufbau, Innen Bodenaufbau, Innen Bodenaufbau, Innen Bodenaufbau, Außen (cm) Bodenaufbau, Innen Bodenaufbau, Außen (cm) Bodenaufbau, Innen Bodenenstand Bodenaufbau, Außen (cm) Bodenenstander Bodenenstand Bodenenstande B
EberGebalaktocks: Inter-Internationals. EberGebalaktocks: Inter-Internationals. TurTurnational kurkunstoomian or, TurTurnational kurkunstoomian or, Asstructuomatische Schiebelör, Asstructuomatische Schiebelör, Asstructuomatische Schiebelör, Asstructuomatische Schiebelör, Asstructuomatische Schiebelör, Asstructuomatische Schiebelör, Asstructuomatische Schiebelör, Conditionalische Schiebelör, Turturatische Schiebelör, Turturatische Schiebelör, Schieberzehbrung Bodenaufbau, Außen (cm) Bodenaufbau, Außen (cm) Turturatische Schiebelör Turturatische Schiebelör Bodeneinstand Bodeneinstand Bodeneinstand Bodeneinstand Schieberzehbau, Außen (cm) Bodeneinstand Bodeneinstand Protocoler (Ariewuk, Schiebelör) Bodeneinstand Schieberzehbau, Außen (cm) Bodeneinstand Bodeneinstand Schieberzehbau, Außen (cm) Bodeneinstand Schieberzehbau, Außen (cm) Bodeneinstand Bodeneinstand Bodeneinstand Schieberzehbau Schieberzehbau Bodeneinstand Schieberzehbau Schie
Eb=Edebalaktocks: Нан-Bickmatesurges. Eb=Edebalaktock: Нан-Bickmatesurges. TurTurhalenzage TurTurhalenzage Asch-kulomatische Schiebelök: Turatseisurgeligenschaften Rechekulomatische Schiebelök: Politikkeisensenzeeigenschaften Rechekulomatische Schiebelök: Turatseisurgeligent, Friederhrang Bodenaufbau, Anden (cm) Bodenaufbau, Außen (cm) Bodenen außen (cm) Boden außen (cm
Ebergebalaktocks: Harbebarneck Ebergebalaktock: Harbebarneck TurTurhalenzage TurTurhalenzage TurTurhalenzage Turtur Aschekulomatische Schiebelök: Politikks: schreische Schiebelök: Politikks: schreische Schiebelök: Politikks: schreische Schiebelök: Politikks: schreische Schiebelök: Turaufschiegenschaften Bodenaufsche Breite/Höhe (cm) Bodenaufsche Strass Din rechtelitikks Bodenaufsch. Außen (cm) Bodenaufsch. Außen (cm) Bodenaufsch. Außen (cm) Bodenaufsch. Außen (cm) Bodenaufsch. Strass Bodenaufsch. Außen (cm) Bodenaufsch. Außen (cm) Bodenaufsch. Strass Bodenaufsch. Außen (cm) Bodenaufsch. Strass Bodenaufsch. Außen (cm) Bodenaufsch. Außen (cm) Bodenaufsch. Strass Bodenaufsch. Außen (cm) Bodenaufsch. Außen (cm) Bodenaufsch. Strass Bodenaufsch. Außen (cm) Bodenaufsch. Strass Bodenaufsch. Strass Bode
Воделейлесь Кы-Кылаканарыс. Пи-Тиглайско: Ан-Нобиликанары. Воделейлесь Ки-Килаканары. Пи-Тиглайско: Ан-Килаканары. Акклакиторайско: Ан-Килаканары. Акклакиторайско: Ан-Килаканары. Акклакиторайско: Ан-Килаканары. Акклакиторайско: Ан-Килаканары. Онокональско: Ан-Килаканары. Акклакиторайско: Ан-Килаканары. Онокональско: Ан-Килаканары. Онокона. Онокональско: Ан-Килаканары. Онокональско: Ан-Килаканары. Онокональско: Ан-Килаканары. Онокональско: Ан-Килаканары. Онокональско: Ан-Килаканары. Онокональско:
Eb=Gebalaktock; I-H=Hokumkasunges. Eb=Gebalaktock; I-H=Hokumkasunges. Tu-Turhalenzage Tu-Turhalenzage Turfurhalenzage Asch-kulomalische Schebelok; Turfilugelanzahl/khnschlag Rehekulomalische Breite/Höhe (cm) Rehekulomalische Breite/Höhe (cm) Mensassungesignet, E-feuchtraungosignet I-Uraufschlagnichtung Bodenaufbau, Innen (cm) OKRR-LK saus OKRR-LK saus Din rechteltes Asch-kulomalische Breite/Höhe (cm) Breiterichtang Primen, al-Außen Din rechteltes Din
Ebe@denaufbau, Innen (cm) Bodenaufbau, Innen (cm) Turaufsahmen Ku-Kunstokfamen TuruTurhaierzuge Turaufsahmen Ku-Kunstokfamen Asch-kulomaische Schebelör, Tureis skopför Rohbeunichtmaß Breite/Höhe (cm) OkiRFB-UK Stars Polinen, a=Außen Minsseumpeignet, F-deuth aungesignet Minsseumpeignet, F-deuth aungesignet Minsseume Minsseumpeignet, F-deuth aungesignet Minsseum Rohbaunichtung Minsseum Rohbaunichtung Rohbaunichtung Minsseum Rohbaunichtung Rohbaunichtung Minsseum Rohbaunichtung Rohbaunic
I=Inner, arkendsocc, I+P+b&unkesungs. I+=Hdsahmen, Ku-Kundsodhahmen, TurTurhakenzage TurTurhakenzage TurTurhakenzage Asstrachadon, Ku-Kundsohahmen, Türtüsendenzahrke Asstrachomatische Schiebeds, Türtüsendenzahrkenschlag Dit nechsähikis Dit nechsähik
Светеконорен Пассия Витеконорен Пассия Ти-Тиглайександо Ти-Тиглайександо Пи-Тиглайександо Пи-Тиглай Средску быласта Пилан Солансейных Сол
Скепенски склавающих с. Панама и склавающия. На-Ниблайтова Ки-Калавающий с. Панама Ти-Ти-Пи-Пи-Пи-Пи-Пи-Пи-Пи-Пи-Пи-Пи- Ти-Пи-Пи-Пи-Пи-Пи-Пи-Пи-Пи- Солайска скласски склавающи с Респиска скласски склавающи с Солайска скласски склавающи с Солайска скласски с ПОП каскиятела Солайска скласски с Солайска скласски с Солайска скласски с Солайска скласски с Солайска скласски с Солайска скласки с Солабо скласки с
Ен∈бемайноск, г.н. нье ньсцикаваширак. Не-Нихаайлоог Ки-Килабойтайл ос. Ти-Тиглайелсиро Спалт Карбири, 5-56кболайх, Татае акорох Спалтее (акок, 8-16040х, 5-56кболайх, Неньбох, Спалтее (акок, 8-16040х, 5-56кболайх, Неньбох, Спалтее (акок, 8-16040х, 5-56кболайх, 1-тее акорох Спалтее акорох Спалтее (акок, 8-16040х, 5-56кболайх, 1-тее акорох Спалтее акорох Спалтее (акок, 8-16040х, 5-56кболайх, 1-тее акорох Спалтее (акок, 8-16040х, 5-56кболайх, 1-тее акорох Спалтее акорох
Eh=Edenski Jakov, Z., Hahkuratsaka sungas. Eh=Edenski Jakov, Ku-Hkuratsaka sungas. Tu-Turhatienzuge D=Dinktor, S-In=Science (2012) D=Dinktor, S-In=Science (2012) D=Din=Science (2012) D=Dinktor, S-In=Science (2012) D
Ehe Edonal Micholox, E. The Hokumaka sunges. Frei-Hoku ahmon Ku-Kunstolmahm en Tu-Turhai enzange De Ondar, Seh-Scholox, Seh-Scholoxik, Thele akcptor Freiburg, R-Rodary, Seh-Scholoxik, Hei-Hubox, Asch-Automatische Schiebetör
Eb=Edelstahtbiockz, Hu=Hotzumtesaungez. H=Hotzahmen, Ku=Kunststottahmen, Tu=Tumhallenzarge
Zargentyp/Material Su=Stahlmitassungsz, Se=Stahleckz, Sb=Stahlbockz, Mir=Metalinahmen
Türblah Paralaria Herbac Osani Bakadı Haralar (Alman Bakadı Baral Ge Cas, Saradı Hig-Hota mi Clas, Saradı Japa HTA- Ge Cas, Saradı Hig-Hota mi Clas, Saradı Japa HTA- Fe uchtraumiz, Horlunatadıratı meridası Felologi
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Appendix

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AOJe ni steanete0		Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generischi))	Innentüren Holz 88,5 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Innentüren Holz 101 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))	Innentüren Holz 113 (Innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Innentüren Holz 113 (Innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Innentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Innentüren Holz 113 (Innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Innentüren Holz 113 (Innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch) (de))	Innentüren Holz 101 (Innenfærbe Dispersionsfarbe scheuerfest (de); Spanplatte (generisch))
Klemmschutzganze H 85 = Bandseite 865 = Bandgegenseite										
nerto&IhedonüT		Resopal 9417-60	Resopal 9417-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60
Drůckergarnitur au Ge D-Drůcker, K-Knauf, S-3ro D-Drůcker, K-Knauf, S-3ro H-Hebel, M-Muschel, 8g-8		à	ā	۵	Kn A	Ğ	KnB	à	Kn A	ă
Drückergarnitur inner D-Drücker, K-Krauf, S-Sto D-Drücker, M-Muschel, Bg-B		ă	۲ ۲	۲ ۲	D,	ъ С	Dr	<u>ت</u>	à	à
Schallschutz Rw'R (e		0	0	0	32	32	32	32	32	32
bristanienebo 8		0	0	0	0	0	0	0	0	0
n sû uA , us dî us ne û bo B		워	q	유	9	0 1	유	위	9	위
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Türəufschləgrichtung i=lnnen, a=Aulsen		.—	i	8	8	8	8	8	-	-
Zargenoberfläche		RAL 9016	RAL 9016	NCS S8000N	NCS S8000N	NCS S8000N	NCS S8000N	NCS S8000N	NCS S8000N	NCS S8000N
Rohbaurichtmaß Brei ok Rre-UK Sauz		101*213	88,5*213	101*213	113,5*213	113,5*213	113,5*213	113,5*213	113,5*205	101*213
Sin wether interaction of the second states of the		ß		Re		Re			Re	Re
n efte ribe negeieste eu Z N=nessemmesenen. F =fe										
Türart D=D rehtür, Sch=Schlebetür F=Faltür, R=Rotlor, S=Sek Pach=Automatische Schiebe		٥	D	Q	D	Q	Q	Q	Q	٩
Zargent/yp/Material Su-Sahlum fasurugsz, Se- Su-Sahlackz, M= Mealt Eb=Edetablockz, Hu=Hu H=Holzahnen, Ku=Kunds H=Holzahnen, Ku=Kunds		Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55
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Türposition A-Aussen, I-Innen, F-Faas		_	1	-	1	Ļ	ſ	1		_
		271 Vorraum WC	270 WC Schülerinnen	281 Flur	201.1 Musikraum	201.2 Musikraum	202.1 Nebenraum Musik	202.2 Nebenraum Musik	203.1 Vorbereitung Physik	203.2 Vorbereitung Physik
SortoseD		g	g	g	g	g	g	8	g	g
	_	5	2	5	2.0	2.(2.0	2.0	2	5

Zargenoberfläche Türs ufschlagrichtung Fürs ufschlagrichtung Bodenaufbau, Außen (cm) Bodenaufbau, Außen (anderen (cm) Bodenaufbau, Außen (cm) Bodenaufbau, Auge
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Zargenoberfišche Türsufschlagrichtung Bodenaufbau, Außen Bodenaufbau, Außen (cm) Bodenaufbau, Außen (cm)
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Zargenoberfiäche Türaufschlegrichtung i≕Innen, a≞Außen Bodenautau, Innen (cm)
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lian entre Magenia Su-Sahlwan fasaungaz, Sa-Sahlecix, Sa-Sahlwan fasaungaz, Sa-Sahlecix, Sa-Sahlwan, Ku, Hu-Hokanhasungaz, Heri+bäz annon, Ku-Hundstoffnähm en, Tu-Tu-thelenzerge
Türbishmajarish Huya Okamidan Sadatauri Minikaki Raiman-Gia ng Gada Sadah Ugu Hada mid Sadatauri Gada Raugankan Minikaki Sadatang Sadagankokoka, Jina Madatanga, Sadatanga, Rene Sakakan Misorish, Jina Madatanga, Sadatakokoka, Minikatanga Sadatanga Herihdian Saga

Türtypen

ACJe ni steaneleO	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	nnentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 101 (innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch))	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))	mentüren Holz 113 (Innenfarbe Dispersionsfarbe scheuerfest (de); Spanplatte generisch) (de))			
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nerto#ihedorûT	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60	Resopal 10622-60			
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Drückergamitur in ne D-Drücker, K-Knauf, S=3 H=Hebel, M=Muschel, Bg:	ā	ā	ā	5	ā			
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Zargentyp, Material Sustantockz, Medensesurgsz, S Sbestantockz, Medens Ebestantockz, Muskura Historizatron, Kuskura Tustoriange	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55	Su Sp40*55		Rahmedicke nemnishneld	17
Türbistem#eñela Hei+us coenteren schrabstrum G∈Gaar,S=Sahl, Hg≓hata Feutrisemür, K+kunastraten	H_stumpf	H_stumpf	H_stumpf	H_stumpf	H_stumpf		leireteM nemrteЯ	Aluminium
noitisoqıüT A-Aussen, I-Innen, F-Fa	L L	L.	1	ſ	ſ		agaussamdA AbmessamdA	76,2*47,5
	Physik	Vorbereitung Chemie	Vorbereitung Chemie	Chemie	EDV		Quelle / 티라eG	A_5832_A1
	204	05.1	05.2	206	207	ange	Tür Nummer	186.1
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	2.0	2.4	2.0	5	2.0	, ž		

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	Klemmschutz ganze Höhe:
	nərləğhədorüT
	-crocoter, N-Milachel, Bg-Böge (prift High and a Boge (prift
	Drückergamitur außen
	.egnstatiot2=2, /hen/H=M, iedeH=H Wigleg68=68, /herbeuM=M, iedeH=H
	Drückergamitur innen Drückergamitur innen
	Schallschutz RWR (eingebauter Zusta
	bristrijene bo 8
	(mo) ne&utban, Außen (cm)
	Bodenaufbau, Innen (cm)
	ne∂uA=s ,nennl=i
	Türaufschlagrichtung
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	synfrethen NIG
	peirtban A\iri aznelegüihüT
	Name of the second seco
	Türənt D=Drehtür, Sch=Schlebetür, T=Teleakoptür F=#attibur, R=Retation, S=Selationaltor, H=H000r, F=#attiburbitare Serbestarion
u	Isense Morgen Steries Su-Station (γρ. Mattering) Su-Station (λατά Su-Station (λατά Su-Station Station) Hetholismen, Ku-Hunsteen Hetholismen, Ku-Hunsteen Tu-Turhienserge
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	ADJə ni steanəte0				
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	Türoberfisichen				
	Drůcke rgarnitur außen C=Drotex, K=¥naut, S=3kotaange, H=Hebel M=Muschel 8g=80gelgriff				
	, agraats coord, c. manwey, account of the Hard of the				
	Drückergarnitur innen				
	Schallschutz Rw'R (eingebauter Zusta		_		
	bnetanienebo 8		_		
	(mo) neûluA ,us dî usnebo B				
	Bodenaufbau, Innen (cm)	enster	≣	enster	
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	Zargenoberfišche	In eLCA mit (Assisten	In eLCA mit o Assisten	
	Rohbaurichtmaß Breite/Höhe (cm) Oknea⊦k saw	Brandschutztür Gang 1.0G Anbau	& 2.0G	Brandschulztür Gang 1.0G Anbau & 2.0G	
	Belinosofinis Div Memory Pressonage Belinosoficial		~	3	
	Partseigen of the sequence of	i	Gas	G G	
	Türart D=D rehnür, Sch=Schlebetür, T=T ele akoptür F=Falttür, R=Rollor, S=Sektonatior, H=Hublor, R=Falttür, R=Rollor, S=Sektonatior, H=Hublor,		8	σ	
ų	Surgentyp/Matterial Su-Surburi fasurngaz, 8Surbickaz, Bo-Surburickasurngaz, Horelanianan Bo-Surburickaz, Hu-Hotumasungaz, H-Hotamien, Ku-Kurburiterio Tu-Tu-Tu-Inaterizage	!	17	17	
Türtype	ibitedenthebbut Antoromenta Satation Ministratics enclands betra arXN ratiples gis au£ antorin site in statistics encland asD+remidinforteruble dimensioner dimensioner arb articular (effecteruble)		Aluminium	Aluminium	
	Türposition Asusen, Iminen, Fillessede Fensterelement		2,74*2,16	2,74*2,16	
			1A_22531_A	1A_22530_A	
	юЯ		186.2, 185	80,283,28	
	Sochoß	061	Anbau	062	

					Component			
Bauteil	Datensatz eLC/	٨			Group	Declared Unit	Menge	Quellen
								2 Wärmepumpen mit a 64
Wärmepumpe	Rohre für Stror	mwärmepump	e (Sole-Wasse	r, Erdsonde) 7	421	piece	2	kW Leistung
								2 Wärmepumpen mit a 64
	Stromwärmep	umpe (Sole-W	asser, Erdsond	e) 70 kW	421	piece	2	kW Leistung
								23 040 1 H04_L-Schema MSK-
								Wärme- u.
Pufferspeicher	Pufferspeicher	(Edelstahl)			421	kg	144	Kälteversorgung_Hauptgebäude_ Rev
								Summe aus Zonen mit
								Lüftung; Dokumente: Zoning
Lüftungsanlage	Lüfter dezentra	al mit WRG (W	(and & Decke)	60 m³/h	431	piece	33	and Energy Simulation IBF
PV	Photovoltaiksy	stem 1000 kW	/h/m ^{2*} a (ohne	Stromgutschr	442	m²	672	Detail PV: 1A_21304LP4_B
Fahrstuhl	Fahrstuhl - Gru	Indkomponent	ten (stockwerk	unabhängig)	461	piece	1	
	Fahrstuhl - Kon	nponenten (st	ockwerkabhän	gig)	461	piece	3	3 Stockwerke (EG-2.0G)
Sockelbetrag		QNG Da	tensatz		410, 420, 430	kg CO2 Äqui./	2761,14	QNG Leitfaden

UMWELT-PRODUKTDEKLARATION nach ISO 14025 und EN 15804+A1 Deklarationsinhaber Porextherm Dämmstoffe GmbH 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.

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



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

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



Hours	occupancy WC		Lig	hting	WC	Hea	ating	WC	Ventilation WC			Service Hot Water			
of the dav	Fr	actior	nal	fra	action	nal	clas	ss-roo	oms	v S	vinter & umme	& r	fra	action	al
								temp.			fractional				
	W	WE	н	W	WE	Н	W	WE	н	W	WE	Н	W	WE	Н
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			1.0	0	
12		0		0.1	0	0	15	15	12	0.5	0		1.0	U	
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		

A	pendix	E:	Schedule of	ⁱ the	Zones:	WC.	Corridors.	and Ut	ilitv	Rooms
• • •						···•,	•••••••••••••••••••••••••••••••••••••••			

Hours of the day	Occup I	oancy Cor Fractiona	rridors I	Ligh	ting Corri fractiona	idors I	Heating Corridors class-rooms temp.			
	W	WE	н	W	WE	Н	W	WE	Н	
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	Occ I R	cupa Utility toom	ncy y Is	Li U R	ightir Utility loom	ng y Is	н	eatir	ıg	Cooling Utility Rooms			Cooling Utility Rooms			Ventilatior Utility Rooms summer		
day	Fra	Fractional			fractional			Utility Rooms		temp.		Rooms winter			fractional			
					temp.				fractional									
	W	WE	Н	W	WE	Н	W	WE	Н	W	WE	Н	W	WE	Н	W	WE	Н
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	
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
14	1	0	0	0.5	0	0	19	17	15
15	1	0	0	0.5	0	0	19	17	15
16	1	0	0	0.5	0	0	17	17	15
17	0	0	0	0	0	0	17	17	15
18	0	0	0	0	0	0	17	17	15
19	0	0	0	0	0	0	17	17	15
20	0	0	0	0	0	0	17	17	15
21	0	0	0	0	0	0	17	17	15
22	0	0	0	0	0	0	17	17	15
23	0	0	0	0	0	0	17	17	15

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_1 EU30117 I EU30123

Linge (c)	Greite (y)	Rahmenhöhe [4]	Gewicht	Anchiumdone	Sockeebinderbox	Kabal Di	Gerotalaantaad Vistan	Montagehinweis: Siehe Montage- <u>und Bentiehsanleihung</u> unter:				
1691,0	990,D	50,0	21	Spehberg	MC4	-800	strukturiert	Montage in horizontaler und vertikaler				
Kristallines	ı Solarmodul		n, y, Lin m	m, 12; z in mm, 10,	3; Gewicht in kg ±0,5			Ausführung möglich Systemspannu bis max. 1000 V Betriebstomperaturbereich -40 bis 85 °C				
Leistungsklassen 235 Wg. 249 Wg. 245 Wg. 250 Wg								Schwar	hlichtverh	alten:		
Leistungss	ortierung		-0/+4,99 (-0/+4,32 %0						Vingo, N	INDER IN	
Aufbau			Glas-Folie- F Elexierte	Glas-Falle-Larninat • Elevierter Alerninismuchmen								
			► Arnchia	Arnch kandose (IP ES) mit 3 Dypano-Dioden						0,0	-20	
			► Witteru	ngsbestländige Räck			600	0,0	-40			
240 km			60 Stuck II	onokristelane sola	Company of Format 120	200 X 139 N	-2		400	-0,4	-60	
Mechanisc	the Belastbark	ait	SHOO BY AL	Mane, 2400 87 598	Retries IDC 61215	Jerweiterber Te	at)		200	-1,2	-80	
Leistungski	lause Ro	eo.lWel X	199.	impo.(A)	Vas.IVI In	JAI	Richtsophe:		100	-6,0	-90	
_	M Bubbaba					landburbnik (s.[A]		Die elektri	chen Daten gelt und AM 1,5.	ten <u>hei 35</u> °C		
250	250	1 3	1,31	8,25	37,90 B,0	12	25	Elaktris	che Elgens	zhaften hei	STCI	
245	245	5 38	1,10	H,2D	37,70 8,3	70	25	LINENGI	cite cigens	scharten per	are.	
240	240	1 34	1,DD	H,1D	37,4D B,0	LD OIL	25	Temperatur-19905131005, TX Inc/cl			TK [56/K]	
235	23	5 2	00,0	8,00	37,10 8,3	SD	25					

400	203	20,00	11,010	ar,40	11,50	6					
Rechétion des Modulairtungsgrades bei Rüchgang der Bestrahlungsstärke von 1000 W/m ² auf 200 W/m ² (bei 25 °C): -0,31 % (absolut); Messiolware (2000 11 %)											
Thermische Eigenschaften:											

Temperatur-1999019906	TK [%/K]
CARRA.	-0,46
Was.	-0,32
UK	0,032

Elektrische Eigenschaften bei NOCT¹:

Leistungsklasse	Boas/W1	Nase M	MR.M	inc (A)				
250	182	27,36	34,82	7,11				
245	177	27,07	3M,D9	6,92				
240	173	26,98	3M,DD	6,84				
285	169	26,87	333,80	6,75				
NOCT: Normal Operation GUDGUBOUGD 40,4 °C: Bestrahlungsstärke 800 W/m ² , AM 1,5, Temperatur 20 °C, Windgeschwinzigkeit In/k, elektrischer Leertauf								

Abmessungen²:





Disselektrischen Kerreprößen sind typische Mittelsente aus dieser Daten bei zukünftigen Fertigungschargen gegeben. rtie für die Gena n Pn

Bosch Solar Energy AG ² Zaich sungen sind nicht malistabspetres. Detail liefte Malie und Tolessmen siehe oben.



Appendix H: Grasshopper canvas of the PV-Simulation