
Evaluating Sustainable Sites, Location and Transportation, and Energy Performance: LEED Criteria in a Platinum-Certified DGNB Building

Master Thesis

**International Master of Science in Construction and Real Estate
Management Joint Study Programme of Metropolia Helsinki and
HTW Berlin**

S0591996

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Submitted on:

04.07.2025

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Acknowledgment

I would like to express my deepest gratitude to my supervisor, Dr.-Ing. Papon Kumar Dev and M.Eng. Richa Srivastava for their invaluable guidance, unwavering support, and insightful feedback throughout this research.

I want to dedicate this work to my beloved father, whom I lost during my studies, a true advocate of education whose encouragement continues to inspire me. My heartfelt thanks go to my mother for her unconditional love and moral support and to my sister, whose wisdom, compassion, and steady encouragement have guided me through every challenge. Your belief in me gave me the strength to persevere on the toughest days. I am also grateful to my friends and former colleagues for their camaraderie and motivation.

Finally, I would like to thank HTW Berlin and Metropolia University of Applied Sciences, Helsinki for providing me with the opportunity to study, explore, and grow.

**Topic: Evaluating Sustainable Sites, Location and Transportation, and
Energy Performance: LEED Criteria's in a Platinum-Certified DGNB
Building**


Background


The fast global changes in every aspect, ecological (e. g. global and local climate changes) micro-economic issues), g. economic crises), and social (e. g. these changes have stirred a need for broader territorial, national and international frameworks for urban development strategy through the establishment of special mechanisms for sustainability assessment and improvement (Hamedani & Huber, 2012). As a result, many eco-friendly building certifications are being adopted around the world (Won, 2014). Certification systems are quantitative standards which are used to measure the concept of sustainable development in any area. Firstly, these systems formulate a set of criteria and a rating system that are used to score projects only in a specific stage of this process. The plan for more sustainable design and build methods is globalized. Nevertheless, there are no mutually comparable evaluation items that have been proposed so far. Therefore, 600 other sustainability rating systems have been popping up around the globe to support the building sustainability movement (Illankoon et al., 2017).

Among the sustainable building tools LEED (Leadership in Energy & Environmental Design) and DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) have gained a considerable attention as credible guidelines. LEED has gained a larger global presence, allowing it to become incorporated into 160 countries across the world (Doan et al., 2017). DGNB is one of the newest certificates and the first one from Germany (the most industrial European country and the most active in the construction and development of sustainable cities) (Hamedani & Huber, 2012).

The aim of this study is to compare the LEED and DGNB certification programs, with an emphasis on particular requirements pertaining to Energy Performance, Location and Transportation (LEED), and Sustainable Sites (LEED). This case study will offer a variety of practical tools for assessing the effect of such systems in defined geographic and cultural surroundings.

The goal of the study is to present a thorough analysis of the methods and scoring standards employed by the two systems, emphasizing their advantages, disadvantages, and similarities. The study will determine how well the selected example complies with LEED criteria while


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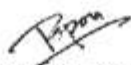
adhering to DGNB principle by using visual and quantitative data. The study will integrate the mentioned theoretical frameworks with the purpose of providing a holistic assessment and interpretation of certification systems complexities and aspects of quality, thus advancing the implementation of sustainable construction strategies and related policies.

Research Gap

Since the aim of these systems is to enhance sustainability, various authors have made comparisons between how different rating systems achieve their desired outcomes. Mostly, this is done by measuring tool (i. e. Rating scale, scorecard) and all the data about it. Won (2014) illustrated the contrasts and the importance of social and economic aspects in green building certification between Korea's G-SEED and Germany's sustainable certification. Cao (2022) showed successful implementation of DGNB Certification System in China, with analysis of the positive effects on quality of project.

Bayhan & Gurgun (2016) studied LEED-certified green buildings in Turkey to identify the successful and the challenging categories, with the aim of improving material and resources performance. Despite the extensive research on both these certification systems, the comparative effectiveness of LEED and DGNB in the German building system remains underexplored. The research focuses on the bridging the gap by conducting a definitive comparative of LEED and DGNB within the context of DGNB-certified building in Germany.

The research will examine the criteria, standards, and methodologies of the LEED and DGNB certification systems, focusing on their application to key aspects such as location, transportation, sustainable sites, and energy performance. Using a DGNB Platinum-certified building as a case study, the study will analyze how each system's principles are implemented and perform in real-world scenarios.



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Research Aim:**Objective Output Matrix**

Sr No.	Specific Objective	Research Questions	Indicators	Data Source	Expected Outputs
1	Evaluating Location and Transportation Criteria (LEED) for a DGNB Platinum-Certified Building in Germany	<p>How does the building's proximity to public transportation comply with LEED's Location and Transportation criteria?</p> <p>What is the accessibility of amenities (e.g., schools, parks, shops) near the building, and how does it influence walkability and connectivity?</p>	<ul style="list-style-type: none"> Proximity to Public Transit: Distance to the nearest bus stop (400m) or train station (800m) based on LEED standards. Environmental Sensitivity: Presence of protected areas, wetlands, or Greenfields near the site. Access to Amenities: Number and diversity of essential services within walking distance. 	<ul style="list-style-type: none"> Google Maps: For measuring distances to transit stops and amenities. GIS tools (e.g., Hamburg Urban Planning Maps): For identifying environmental sensitivity. Satellite and Aerial Imagery: For observing site characteristic 	<ul style="list-style-type: none"> A detailed analysis of the building's transportation accessibility and walkability in comparison to LEED standards. Insights into environmental sensitivities and compliance with green building principles.
2	Analyzing Sustainable Sites Criteria (LEED) with a focus on Ecological and Urban Development Impacts	<p>What sustainable site features, such as site assessments, open spaces, heat island reduction measures, and landscaping, are incorporated into the building's design?</p> <p>How does the building address habitat protection or restoration in</p>	<ul style="list-style-type: none"> Heat Island Effect Reduction: Percentage of reflective materials and vegetative coverage to reduce heat accumulation. Percentage of site as open space, accessibility, vegetated areas, ecological value, connectivity with surroundings. Biodiversity and Landscaping: Presence of native vegetation or landscaping designed 	<ul style="list-style-type: none"> Architectural Drawings LEED Certification Manuals: For Sustainable Sites scoring criteria. 	<ul style="list-style-type: none"> A comprehensive evaluation of the building's sustainable site features, including storm-water systems, heat island reduction, and biodiversity enhancements. Visual data (maps, annotated images) illustrating the building's alignment with LEED

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		line with LEED's Sustainable Sites criteria?	to preserve or enhance biodiversity.		Sustainable Sites criteria.
3	Assessing Energy Performance in a DGNB Platinum-Certified Building	How do material properties, wall thickness, and the size and placement of windows influence the building's energy performance?	<ul style="list-style-type: none"> Thermal conductivity (U-value), wall thickness, and glazing type for windows, along with window-to-wall ratio (WWR) and orientation. 	<ul style="list-style-type: none"> Building Energy Simulation Software 	A quantified assessment of the building's energy efficiency against LEED standards.
		What role do building materials and design features, such as wall thickness and window openings, play in optimizing energy efficiency?			

Methodology

1. Perform an in-depth literature review of the LEED and DGNB certification systems, emphasizing their criteria, methodologies, and results.
2. Collect data on the LEED and DGNB certification systems to gain insight into their scoring structures and their use in sustainable building practices.
3. Select a DGNB Platinum-certified building in Germany to use as a case study for analysis.
4. Utilize energy simulation software and spatial analysis tools to evaluate the performance of the case study building against LEED certification criteria.
5. Compare the building's sustainability performance under the DGNB system with LEED standards, highlighting areas of alignment, strengths, and gaps.
6. Examine the results to identify ways to optimize the LEED and DGNB systems for improving sustainability in the built environment.

Tentative Plan


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1. **January–February:** Literature review, data collection, and case study selection completed.
2. **March–April:** Case study simulations, performance assessment, and comparison completed.
3. **May–June:** Initial findings, analysis, thesis writing, and revisions completed.
4. **July:** Final thesis submission.

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**Specifications for the Master Examination
according to § 9 and 10 Examination Regulations for the Master Study Programme
Construction and Real Estate Management**

1. Master Thesis, Examination Commission

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(1) Topic of the Master Thesis:

Evaluating Sustainable Sites Location and Transportation and
Energy Performance: LEED Criteria's in a Platinum-Certified
DGNB-Building

(2) Examination Commission

Chairperson can be empty till confirmation _____

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(3) Thesis Period

Date of Issue 15. APR. 2025

Closing Date 4th of July 2025
Deadline 4th of July 2025

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Berlin, 15.04.2025

Tooba Hafeez

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ABSTRACT

This study evaluates a DGNB Platinum–certified building against selected LEED v4 BD+C criteria Location & Transportation, Sustainable Sites, and Energy Performance using the Troplo Kids daycare center in Hamburg, Germany, as a case study. A mixed-methods design combined quantitative measures (transit stop distance, land-use density, envelope U-values) from geospatial datasets and technical reports with qualitative analysis of site observations and design documentation. In Location & Transportation, the project scored 10.5 out of 12 points (87.5%), benefiting from proximity to U-Bahn (750m) and bus (250m), high surrounding density, diverse local amenities, and full bicycle facilities. However, it underperformed in parking reduction and green-vehicle infrastructure. In Sustainable Sites, it achieved 3 of 6 points (50%) by providing 76% open space (30% vegetated) and a comprehensive site assessment, yet did not meet the LEED thresholds for heat-island mitigation or greenfield preservation. Energy Performance revealed opaque U-values of 0.16 W/m²K, triple-glazed U-values of 1.14 W/m²K, and a 58.2% reduction in final energy consumption compared to EnEV 2009 benchmarks, indicating potential maximum LEED energy points. The building’s normalized mini-rating of 75% corresponds to LEED Platinum certification. The dual certification outcome highlights the complementary strengths of DGNB’s life cycle oriented, context-sensitive assessment and LEED’s quantitative, performance-driven benchmarks. Findings highlight the importance of integrated design strategies for transit-oriented development, ecological site stewardship, and high-performance envelopes, offering guidance for harmonizing international standards with regional practices and informing designers, consultants, and policymakers in pursuing dual or hybrid certification schemes.

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LIST OF ABBREVIATIONS

BD+C	Building Design and Construction
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen
EnEV	Energieeinsparverordnung
FAR	Floor Area Ratio
GBRS	Green Building Rating System
GEG	Gebäudeenergiegesetz
GFA	Gross Floor Area
GIS	Geographic Information System
HVV	Hamburger Verkehrsverbund
ID&C	Interior Design + Construction
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
LT	Location and Transportation
LTc	Location and Transportation Credit
RS	Rating System
SR	Solar Reflection
SRI	Solar Reflectance Index
SS	Sustainable Sites
SSc	Sustainable Sites Credit
USGBC	U.S Green Building Council
WWR	Window-to-Wall Ratio

CHAPTER 1 INTRODUCTION

1.1 Background

In recent decades, growing concerns about environmental degradation and climate change have led to increased global attention on energy consumption and greenhouse gas (GHG) emissions. According to Lu et al. (2015), the world is currently facing a critical situation in conserving energy and reducing GHG emissions, which has motivated researchers and professionals to develop innovative technologies, frameworks, and renewable resources.

The building construction significantly contributes to global environmental concerns, particularly in terms of energy consumption and greenhouse gas (GHG) emissions. According to international energy projections, global energy use was expected to rise by over 50% between 2010 and 2040, with buildings anticipated to remain the dominant energy-consuming sector during that period (Wan, Li, Liu, & Lok, 2011). In 2012, for instance, buildings were responsible for approximately one-third of the world's total energy use and GHG emissions (Jeon et al., 2013; Ma et al., 2017). Within the European Union (EU), the building sector is especially impactful, responsible for 42% of energy consumption, GHG emissions of 35%, material extraction of 50 %, and around a third of water use and waste generation (Mrad & Ribeiro, 2022). Residential buildings contribute significantly to these figures, and the impact is expected to increase in coming years (Braulio-Gonzalo, Jorge-Ortiz, & María, 2022). Numerous studies indicate that various stages of a building's life cycle, ranging from construction to demolition, collectively account for nearly 30–40% of global energy usage and emissions. (Roh, Tae, Suk, Ford, & Shin, 2016).

Given this substantial environmental footprint, sustainable construction has become a global priority. In recent years, growing focus has been placed on pressing environmental concerns, including energy storage solutions, assessment of environmental impacts, and the management of waste produced by demolition and construction processes. Governments and institutions have responded by introducing various sustainability guidelines and policies at both national and international levels (Alshamrani, Galal, & Alkass, 2014). Sustainable construction is now widely supported by governments, environmentalists, and industry stakeholders due to its potential to mitigate environmental impacts (Kibert, 2016). This attention is further intensified by projections indicating that the global population could rise to approximately 9.8 billion by the year 2050, placing additional pressure on resources and the built environment (UNDESA,

2017), the demand for energy, raw materials, and infrastructure will surge, underscoring the need for efficient and resilient construction practices.

Sustainability in the built environment encompasses not only environmental but also economic and social considerations. Ferro et al. (2017) emphasized that sustainability transcends organizational boundaries and directly influences operational practices. While early research focused predominantly on environmental factors, there is growing recognition of the need to address sustainability pillars called triple bottom line: planet, people, and profit (Obringer & Nateghi, 2021). To support this shift, stakeholders must holistically design, construct, and manage buildings while considering sustainability across the life cycle.

Employing assessment tools that measure the sustainability of buildings across their entire life cycle is essential for advancing towards a more sustainable built environment. These tools support decision-making by addressing social, environmental, and economic dimensions. In this context, green building rating systems have emerged as a practical mechanism for assessing and guiding sustainable building practices. These tools evaluate the sustainability performance of buildings using predefined criteria across various domains such as energy, water, waste, land use, and transportation. Some systems extend their assessment to economic and social aspects as well (Haapio & Viitaniemi, 2008; Lazar & Chithra, 2021). Among the earliest GBRs was BREEAM, introduced in the UK in 1990, followed by the widely adopted LEED system developed in the United States (Kale & Jain, 2022). Over time, these systems have grown to fulfill the specific needs of different regions, climates, and building typologies (Lazar & Chithra, 2021). Today, the World Green Building Council lists more than 58 rating systems administered by national councils, including well-known examples such as Japan (CASBEE), Australia (Green Star), France (HQE), Green Globes (North America), and GBTool (South Africa) (Marchi, Antonini, & Politi, 2021).

More broadly, the use of international standards such as ISO 14000 and European Norms (EN) has become increasingly prevalent in construction for sustainability (Krizmane, et al., 2016; Tam, et al., 2019). These frameworks provide consistency and benchmarking tools to compare sustainability outcomes across contexts. The global push toward sustainability was further amplified by the approval of Sustainable Development Agenda 2030, which encourages countries to align national practices with the 17 SDG (Martínez-Zarzoso & Maruotti, 2011). As noted by Asdrubali et al. (2015), the sustainability movement is expanding beyond

individual buildings to influence entire urban systems, compelling rating systems to evolve in response to industry and policy expectations.

In addition to these systems, Germany's DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) represents a second-generation rating framework that places greater emphasis on life cycle assessment and performance-based criteria assessment (Ali & Nsairat, 2009). Compared to LEED, which historically concentrated more on environmental indicators such as energy and materials, DGNB adopts a more balanced approach by integrating economic and social dimensions into its evaluation structure (Qadir, Haddad, & Hamdan, 2019). This distinction has been acknowledged in comparative studies, which suggest that DGNB offers a more holistic understanding of sustainability (Doan, et al., 2017).

Although GBRs differ in structure and methodology, most follow one of two core approaches: a point-based system where indicators are assigned credits, or a life cycle assessment method that evaluates environmental impact over the building's lifetime (Marjaba & Chidiac, 2016). LEED, for instance, has evolved to include more stringent requirements over time, introducing new categories and mandatory criteria to combat greenwashing and promote real performance improvements. DGNB goes a step further by requiring all criteria not just some to be met, thereby strengthening accountability.

1.2 Problem Statement

Green building embraces a comprehensive and integrated approach to sustainability based on the recognition that built environment significantly influences both the natural ecosystem and human well-being. Green building practices aim to decrease negative and increase positive effects across the entire life cycle of a structure (Kriss, 2014). In support of this concept, several certification frameworks have been introduced to evaluate the environmental performance and overall sustainability of buildings, which includes water and energy efficiency, indoor quality of environment, and consumption of resource (Mohamed, 2020).

LEED has emerged as one of the most extensively implemented worldwide. As of 2024, more than 195,000 buildings across 186 countries had achieved LEED certification, supported by over 205,000 accredited professionals (Kaplow, 2024). Its scope extends across new and existing buildings, homes, neighborhoods, and even airports, and it has evolved over time to include more holistic elements. Recent updates to the system introduced new credit areas,

including location & transportation, integrative process while also placing greater focus on performance tracking and transparency in material selection (USGBC, 2019).

On the other hand, the DGNB (German Sustainable Building Council) certification system, introduced in 2009, has established itself as a highly advanced and internationally recognized standard (Qadir, Haddad, & Hamdan, 2019). It evaluates sustainability across six categories with more balanced weighting: environmental (25%), economic (25%), sociocultural and functional (25%), technical (10%), process (10%), and site quality (5%) (Elariane & Dubé, 2024). Unlike LEED, DGNB places strong emphasis on life-cycle performance and regional applicability (Qadir, Haddad, & Hamdan, 2019).

While both LEED and DGNB promote sustainable construction, their methodologies, scope, and underlying priorities differ considerably. LEED focuses predominantly on environmental metrics like water, indoor quality of air and energy, using a point-based system with prerequisites and optional credits. In contrast, DGNB's approach is more holistic, incorporating economic and sociocultural criteria alongside environmental ones. DGNB was specifically developed to address gaps left by earlier systems like BREEM and LEED in terms of life-cycle and balanced sustainability assessments.

Nevertheless, this conceptual depth does not necessarily translate into greater practical alignment. Ferrari et al. (2022) found that DGNB demonstrated lower conformity (68%) with the European Commission's Level(s) sustainability framework than LEED (81%), highlighting a gap between theoretical intent and measurable outcomes. In Europe, DGNB certification system is recognized for its thorough and stringent evaluation criteria, making it one of the most comprehensive frameworks for assessing sustainable building practices.

Despite Germany's dual market for DGNB and LEED, there is no empirical, building-level analysis that tests how a DGNB Platinum project performs when measured against core LEED v4 BD+C criteria. Without this comparison, designers cannot know whether DGNB's rigorous life-cycle approach guarantees compliance with internationally recognized LEED benchmarks leaving a blind spot for multinational projects and regulatory harmonization.

Various scholars have compared rating tools across different countries. Won (2014) illustrated the contrasts and the significance of social and economic aspects in green building certification between Korea's G-SEED and Germany's sustainable certification. Cao (2022) showed the

successful implementation of the DGNB Certification System in China, with analysis of the positive effects on project quality. Bayhan & Gurgun (2016) studied LEED-certified green buildings in Turkey to identify the successful and the challenging categories, with the aim of improving materials and resources performance. A few studies directly evaluate LEED criteria in buildings certified under DGNB within Germany. This limits practical insight for designers, consultants, and policymakers navigating between systems.

Therefore, this research study purposes to bridge that gap through conducting a case-based evaluation of a DGNB Platinum-certified building in Germany against LEED v4 credits. The study focuses particularly on three LEED categories, Sustainable Sites, Location & Transportation, and Energy performance. This study will fill that blind spot by applying a mini-LEED credit assessment to the Beiersdorf Troplo Kids Daycare Center building in Hamburg, providing practitioners and regulators with critical evidence on cross-system compatibility.

The lack of empirical building-level studies on this topic restricts informed decision-making for sustainable design, and underscores the relevance and urgency of this research. Moreover, given Germany's leadership in sustainable architecture and the growing demand for dual or harmonized certifications, understanding the compatibility and tensions between DGNB and LEED is vital for aligning international best practices with local standards.

1.3 Research Objectives

This research study aims to conduct a comparative evaluation of the LEED and DGNB certification systems by applying selected LEED criteria to a DGNB Platinum-certified building in Germany. The objectives are:

1. Evaluating Location and Transportation Criteria (LEED) for a DGNB Platinum Certified Building in Germany
2. Analyzing Sustainable Sites Criteria (LEED) with a focus on Ecological and Urban Development Impacts
3. Assessing Energy Performance in a DGNB Platinum Certified Building

1.4 Research Questions

In accordance with the research objectives, following are the research questions:

1. How does the building's proximity to public transportation comply with LEED's Location and Transportation criteria?
2. What is the accessibility of amenities (e.g., schools, parks, shops) near the building, and how does it influence walkability and connectivity?
3. What sustainable site features, such as site assessments, open spaces, heat island reduction measures, and landscaping, are incorporated into the building's design?
4. How does the building address habitat protection or restoration in line with LEED's Sustainable Sites criteria?
5. How do material properties, wall thickness, and the size and placement of windows influence the building's energy performance?
6. What role do building materials and design features, such as wall thickness and window openings, play in optimizing energy efficiency?

1.5 Methodology

This research methodology employs a mixed-methods case study approach to evaluate the sustainability performance of the DGNB Platinum-certified Beiersdorf Troplo Kids daycare center in Hamburg. The quantitative analysis draws on GIS data to measure factors such as transit proximity, land-use ratios, and open space, benchmarked against LEED v4 BD+C School requirements. Qualitative insights are derived from technical reports and site observations to assess contextual features like landscaping, habitat protection, and urban connectivity. Due to data access limitations, energy performance modeling was not conducted; instead, envelope characteristics (U-values, glazing type, and window-to-wall ratio, or WWR) were examined through verified documentation. This integrative design allows a focused comparison of selected DGNB and LEED credits while acknowledging the broader certification frameworks.

CHAPTER 2 LITERATURE REVIEW

2.1 Purpose of Green Building Rating System

A Rating System (RS) is a tool designed to classify objects by evaluating their performance against relevant requirements (Marchi, Antonini, & Politi, 2021). In the context of assessment of sustainability, a GBRS evaluates the environmental and social performance of buildings relative to baseline criteria such as regulatory standards or comparative benchmarks. Such systems are used to assess how well a building performs in certain areas and to determine whether it meets specific environmental targets or standards assign recognition based on the level of performance achieved (Florez, 2020) .

Given the multidimensional nature of sustainability, encompassing water, energy efficiency, water usage, indoor quality of environment, and site location, GBRS integrate diverse performance indicators into a unified assessment. This involves a weighted scoring process that balances different criteria, ultimately producing a single grade that reflects the sustainability of complete building (Marchi, Antonini, & Politi, 2021). The rating is typically issued by an independent third-party organization, which “classifies” buildings to communicate their level of green performance.

Various terms are used interchangeably in the literature to describe these tools, including green building certifications, sustainable building assessment systems, and protocols (Illankoon & Tam, 2019). Despite minor methodological differences, the primary function of GBRS is to recognize and endorse sustainable building practices, often through voluntary market-driven mechanisms that push the construction industry towards improved environmental stewardship.

2.2 Development of GBRS

The terms “sustainable” and “green” have been widely adopted in discussions around environmentally conscious construction (Ragheb, El-Shimy, & Ragheb, 2016). These concepts generally emphasize the effective use of energy and land sources, water conservation, enhancement of both indoor and outdoor air quality, and a greater reliance on recycled or renewable materials (Li, Wei, Li, & Yao, 2016). While the definition of green buildings has evolved over time, it is now commonly understood to encompass architectural practices that

promote health, relevance, efficiency, and harmony with nature—while also maximizing resource savings (land, energy, materials, and water), minimizing environmental impact, and limiting pollution throughout the life cycle of a building. One of the earliest formal definitions of sustainable development was offered by the Brundtland Commission in 1987, describing it as development that meets current needs without undermining the ability of future generations to meet their own (Lorenz & Lützkendorf, 2008).

The emergence and evolution of GBRS must be understood against the backdrop of growing global challenges such as climate change and resource depletion. The built environment is a significant contributor to these issues, accounting globally for approximately 31% of final energy use, 54% of electricity demand, and 23% of energy-related CO₂ emissions, with a substantial portion derived from fossil fuel consumption (Ürge-Vorsatz, et al., 2012). Similarly, in Europe, buildings represent nearly 40% of energy consumption and 36% of greenhouse gas emissions (Al-Sallal, 2014).

Moreover, the construction sector consumes over 30% of natural resource extraction and 25% of solid waste generation worldwide (Benachio, Freitas, & Tavares, 2020). Water use is also considerable, with over 17% of freshwater consumption attributed to building construction and operation worldwide (Say & Antony, 2008). Beyond environmental impacts, building quality affects occupant health and community well-being through factors such as indoor air pollutants and thermal discomfort.

Despite these significant impacts, the building sector offers substantial potential for emission reductions, primarily due to the flexibility in demand management (Berardi, 2012). Consequently, the concept of environmentally-friendly buildings has gained increasing recognition globally, spurring the development of regulations, codes, and voluntary tools aimed at improving building sustainability.

International policy frameworks, such as the United Nations' 2030 Agenda for Sustainable Development, specifically target sustainable cities and clean energy (SDGs 11, 7, and 9). At the regional level, the European Union has implemented directives focused on improving energy performance in buildings, including EPBD III (EU/2024/1275, EPBD) (Commission, 2024). Nonetheless, mandatory policies currently cover less than half of building-related energy consumption and emissions, highlighting the essential role of voluntary initiatives like GBRS to complement regulatory measures (Skillington, Crawford, Warren-Myers, &

Davidson, 2022). Up to date, Green (GRE) buildings embrace environmental improvements while Sustainable buildings focus on 21 four main pillars, including environmental (ENV), social (SOC), economic (ECO), and institutional issues (INS) (Sharifi & Murayama, 2014).

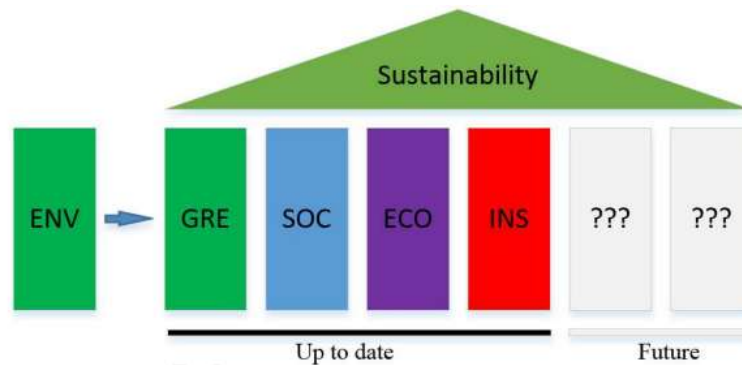


Figure 2.1 Sustainability Pillars (Doan, et al., 2017)

Overall, GBRs (GBRs) are voluntary, market-oriented frameworks developed by independent third parties to evaluate sustainability across multiple criteria. These systems promote the adoption of practices that are socially responsible, environmentally sound, and economically feasible throughout the processes of designing, constructing, and managing buildings—or even entire neighborhoods. The concept merges two distinct components: green building principles and a structured scoring methodology.

2.3 Global Diffusion of GBRS

While individual environmental aspects such as indoor air quality had been evaluated in earlier periods, the development of comprehensive multi-criteria GBRS represents a milestone in sustainable construction. Unlike technical approaches such as Life Cycle Assessment (LCA), GBRS offer a more user-friendly and integrative method by aggregating diverse sustainability indicators into a single assessment framework (Marchi, Antonini, & Politi, 2021).

The Building Research Establishment Environmental Assessment Method (BREEAM), launched in the United Kingdom in 1993, was the first GBRs to adopt a multi-criteria approach (Marchi, Antonini, & Politi, 2021). Over time, BREEAM has established itself as one of the most comprehensive and internationally recognized frameworks for assessing the environmental performance of buildings (Marjaba & Chidiac, 2016). It is widely used across Europe and in numerous other countries reportedly influencing practices in over 72 nations (Soulti & Leonard, 2016). As of June 2025, BREEAM had verified more than 1,025,000

buildings and registered around 2.9 million projects across 104 countries (BREEM, 2025). Its role as the first formal sustainability assessment tool has significantly shaped the global development of green construction practices. By introducing a structured methodology for evaluating sustainability, BREEAM laid the groundwork for the emergence of other national systems. One notable example is the LEED (LEED), established by the U.S. Green Building Council in 1998, which is now widely acknowledged as one of the most influential and widely adopted GBRs globally (USGBC, LEED rating system, 2025). Similarly, Japan introduced the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in 2001, further extending the international momentum toward sustainable building standards (Wong & Abe, 2014).

Recognizing the need for global applicability, the Natural Resources Canada led the development of the SBMethod in the late 1990s, designed as a common framework adaptable to regional and national contexts. This framework resulted in several derivative tools such as Verde (Spain), SBTool PT (Portugal), SBTool CZ (Czech Republic), and SBTool IT (Italy), with the latter renamed the ITACA protocol in 2011 (Marchi, Antonini, & Politi, 2021).

By 2004, the number of GBRS worldwide exceeded 600, reflecting the diverse environmental priorities and building characteristics of different countries (Reed, Bilos, Wilkinson, & Schulte, 2020). However, this proliferation posed challenges for cross-comparison and international collaboration due to varying parameters and metrics.

To address these issues, international standards such as ISO 21931-1:2010 (Framework for Methods of Assessment of the Environmental Performance of Construction Works) and ISO 15643-1:2010 (Sustainability Assessment of Buildings) were established to harmonize assessment methods (Marchi, Antonini, & Politi, 2021).

Today, numerous rating systems operate globally, with the World Green Building Council listing 58 tools managed by its national councils. Besides BREEAM, LEED, and CASBEE, other prominent systems include DGNB (Germany), Green Star (Australia), HQE (France), Green Globes (US and Canada), and GBTool (South Africa) (Marchi, Antonini, & Politi, 2021). Thousands of buildings have been certified under these schemes, evidencing their widespread acceptance and influence in promoting sustainable building practices.



Figure 2.2 Initial 25 Years of GBRs (Hosey, 2017)

2.4 Rating Systems Evaluation Criteria

GBRs function by assessing how well projects meet specific environmental goals and performance standards, ensuring that developments remain resource-efficient and environmentally responsible throughout their entire lifecycle (Buildings, 2025). These systems offer a range of benefits, including:

- Establishing clear environmental targets,
- Facilitating the achievement of measurable sustainability goals,
- Enabling consistent monitoring of environmental performance,
- Allowing project teams to demonstrate sustainability outcomes to external stakeholders,
- Providing a basis for tracking and showcasing progress over time, and
- Enhancing environmental awareness and education within the construction and design sectors.

2.4.1 Scoring methods for sustainable rating systems.

In order to standardize the evaluation of buildings, scoring systems have been developed based on a common set of components. While this overall framework is generally adopted across all major GBRs, variations in implementation may lead to notable differences in specific elements (Bernardi, Carlucci, Cornaro, & Bohne, 2017). These core components typically include

- **Categories:** Defined areas of assessment that address various aspects of a building's environmental performance.
- **Scoring System:** A structured method for awarding points or credits based on the level of performance achieved in each evaluated area.
- **Weighting System:** The process of assigning relative importance to each category within the scoring model, reflecting its contribution to overall sustainability.
- **Output:** A clear and comprehensive presentation of the building's environmental performance results, derived from the scoring phase.

2.5 Leadership in Energy and Environmental Design (LEED)

2.5.1 History and Development

The LEED certification program is widely regarded as the most prominent and internationally recognized green building certification system (Pushkar, 2020). Established in 1993 and headquartered in Washington, D.C., the U.S. Green Building Council (USGBC) initiated the development of LEED in collaboration with a diverse group of stakeholders—including architects, real estate professionals, homeowners, legal experts, and industry representatives. The primary objective was to create a standardized framework for evaluating and comparing the sustainability of buildings. The first official release, LEED v1.0, was launched in 1998 (Awadh, 2017), followed by successive updates: Version 2.0 in 2000, Version 2.1 in 2002, Version 2.2 in 2005, and Version 3.0 in 2009. LEED v4, a more comprehensive iteration, was introduced in 2013 (Lessard, Anand, Blanchet, Frenette, & Amor, 2017). In response to the growing demand for improved energy efficiency in buildings—particularly in the Energy and Atmosphere (EA) credit category, USGBC released LEED v4.1 in 2019 (Dhuoki & Çağnan, 2021). Notably, this version did not completely replace v4, allowing project teams to register under either set of criteria, depending on their preferences and project needs (Marzouk, 2024).

The evolution of the *Energy and Atmosphere* credit category in LEED reflects ongoing efforts to enhance the environmental performance of building design and construction practices.

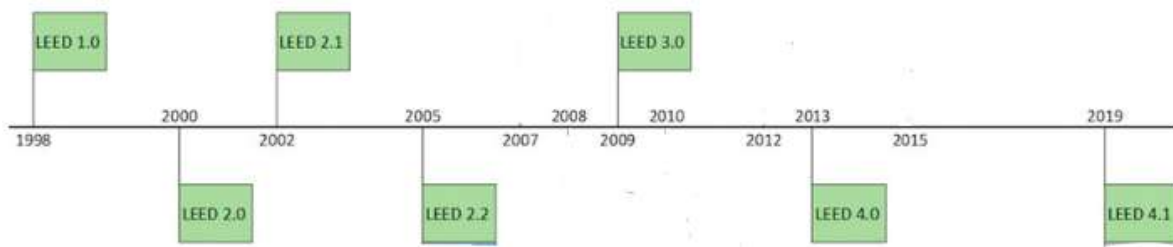


Figure 2.3 LEED Development over the years (Doan, Tran, Aigwi, & Naismith, 2023)

LEED v5 is the latest version of the LEED GBRs. It was officially launched by the U.S. Green Building Council (USGBC) in early 2023 and is now open for new project registrations. LEED v5 represents a significant update, with a greater emphasis on decarbonization, human and ecological health, and resilience. (USGBC, LEED v5-The best buildings use LEED, 2025)

LEED is an independent, third-party certification system that offers a standardized approach to evaluating the environmental performance of a wide range of building types (Pushkar, 2020). It is applicable to nearly all types of construction projects, including buildings, homes, and communities, and serves as a comprehensive framework for developing spaces that are healthy, energy-efficient, and cost-effective.

The system equips building owners and managers with a structured method for integrating practical, measurable strategies into the design, construction, operation, and maintenance of green buildings. It enables the consideration of environmental and social criteria like as site selection, water and energy efficiency, material usage, and indoor environmental quality alongside financial considerations, supporting a holistic approach to sustainable development.

2.5.2 LEED Rating Systems

LEED offers specialized rating systems, each tailored to a specific building typology or project phase (USGBC, LEED rating system, 2025).

- LEED for Building Design and Construction BD+C: Designed for buildings undergoing new construction or major renovations.

- LEED for Operations and Maintenance O+M: Targeted at existing buildings undergoing performance upgrades with minimal structural changes.
- LEED for Interior Design and Construction ID+C: Applies to projects focused on the complete interior fit-out of spaces.
- LEED for Neighborhood Development ND: Developed for new or redeveloped land projects that incorporate residential, non-residential, or mixed-use spaces.
- Homes: Intended for residential projects, including single-family houses, low-rise multi-family buildings (one to three stories), and mid-rise multi-family structures (four to six stories).
- Cities and Communities: Aimed at entire urban areas or specific sections within cities. Leveraging the Arc performance platform, this category allows for monitoring and managing key urban metrics such as water and energy consumption, waste management, transportation, and overall quality of life.



Figure 2.4 LEED Rating Systems

2.5.3 Certification Levels

The LEED certification operates on a point-based system, where credits are awarded for meeting specific sustainability criteria. A building's certification level is determined by the total number of points achieved upon completion and assessment of the project (USGBC, Surrounding density and diverse uses (Schools), 2014). The system allows for a maximum of 110 points, with point allocation varying slightly depending on the project type. The highest weight is typically assigned to the Energy and Atmosphere category, reflecting its critical role in environmental performance. Based on the final score, a project may earn one of four certification levels, each representing a different degree of sustainable achievement.

Level of certification	Score
Not Certified	0-39
Certified	40-49
Silver	50-59
Gold	60-79
Platinum	80-110

Figure 2.5 LEED Certification Levels

2.5.4 Assessment categories

Earning LEED certification from the U.S. Green Building Council (USGBC) is a detailed and often time-intensive process, involving numerous criteria, prerequisites, and regulatory requirements (Pham, Kim, Lee, & Ahn, An investigation of the selection of LEED version 4 credits for sustainable building projects., 2020). Within the LEED framework, specific credits are assigned point values, allowing projects to accumulate points across various sustainability dimensions. In addition to these credits, certain mandatory prerequisites must be fulfilled, although they do not contribute to the overall score. In the LEED v4 BD+C rating system, points are distributed across key categories, each focusing on a particular aspect of sustainable building performance (USGBC, LEED v4 BD+C: New Construction, 2019).

- **Integrative Process (IP):** promote early-stage collaboration among stakeholders in the building design and planning phases. It is iterative, cross-disciplinary, and performance-driven. It seeks to identify synergies among systems and make sustainability-driven decisions before major design and cost commitments are made.
- **Sustainable Sites:** This category evaluates the environmental impacts associated with the building site, aiming to reduce the negative effects of construction activities and manage stormwater runoff effectively.
- **Water Efficiency:** Focuses on minimizing water usage and encouraging the reuse of rainwater. It encompasses strategies for water conservation, efficient plumbing systems, and sustainable water management within the building.
- **Energy and Atmosphere:** Emphasizes strategies for enhancing energy performance, integrating renewable energy sources, and implementing systems to monitor and manage building energy use effectively.
- **Materials and Resources:** This section assesses the selection of construction materials with an emphasis on low environmental impact, cost efficiency, and minimal maintenance. It

also addresses waste reduction and considers the environmental cost of transporting materials.

- **Indoor Environmental Quality:** Prioritizes the health and comfort of building occupants by evaluating factors such as indoor air quality, thermal comfort, lighting, and overall interior environmental conditions.
- **Innovation in Design:** Encourages the adoption of creative and forward-thinking approaches that enhance sustainability beyond standard LEED criteria through innovative design solutions and project strategies.
- **Regional Priority Credits:** These credits reward project teams for addressing region-specific environmental issues by using locally sourced materials and adapting their design strategies to reflect regional needs and priorities.
- **Location and Transportation:** Recognizes projects that are situated in developed, accessible areas with robust transportation options. It also considers the impact of development restrictions and promotes site selection that supports sustainable commuting and reduced vehicle dependency.

Table 2.1 LEED Categories and Credits

Categories	Weightage	Credits	Aspects
Integrative Process	0.90	1	<ul style="list-style-type: none"> • Early collaboration • System interconnectivity • Whole-building analysis • Informed decision-making
Sustainable Sites SS	10.90	12	<ul style="list-style-type: none"> • Construction Activity pollution prevention (prerequisite 1) • Sustainable Site • Site Development- Protect or restore habitat
Location & Transportation	13.63	15	<ul style="list-style-type: none"> • Open Space • Sensitive land protection • High Priority Site • Surrounding Density and Diverse Uses • Access to Quality Transit • Bicycle Facilities • Reduced Parking Footprint • Green Vehicles

Water Efficiency WE	10.90	12	<ul style="list-style-type: none"> • Outdoor Water Reduction (Prerequisite 1) • Indoor Water Reduction (Prerequisite 2) • Building Level Water Metering (Prerequisite 3) <ul style="list-style-type: none"> • Outdoor Water Reduction • Indoor Water Reduction • Cooling Tower Water Use • Water Metering
Energy and Atmosphere EA	28.18	31	<ul style="list-style-type: none"> • Fundamental Commissioning of Building Energy System (Prerequisite 1) • Minimum Energy Performance (Prerequisite 2) • Fundamental Refrigerant Management (Prerequisite 3) <ul style="list-style-type: none"> • Building Level Energy Metering • Optimize Energy Performance • On-site Renewable Energy • Enhanced Commissioning • Enhanced Refrigerant Management • Renewable Energy Production • Advanced Energy Metering • Demand Response • Green Power and Carbon Offset
Material and Resources	11.81	13	<ul style="list-style-type: none"> • Storage and Collection of Recyclables (Prerequisite 1) • Construction and Demolition Waste Management Planning (Prerequisite 2) • Building Lifecycle Impact Reduction

			<ul style="list-style-type: none"> • Environmental product declarations • Sourcing of Raw Materials • Material Ingredients • Construction and Demolition Waste Management
Indoor Environment Quality IEQ	14.54	16	<ul style="list-style-type: none"> Minimum Indoor Air Quality Performance (Prerequisite 1) • Environmental Tobacco Smoke (ETS) • Control (Prerequisite 2) Enhanced Indoor Air Quality Strategies • Acoustic Performance Indoor Air Quality Assessment • Construction Indoor Air Quality Management Plan • Low-Emitting Materials • Quality View • Thermal Comfort—Design • Daylight Interior Lighting
Innovation in design	5.45	6	<ul style="list-style-type: none"> Innovation in Design LEED Accredited Professional
Regional Priority	3.64	4	Regional Priority
Total	100%	110	

2.5.5 Certification Process

To initiate the certification process, a project must first be registered online through the Green Building Certification Institute (GBCI). While including a LEED Accredited Professional (LEED AP) on the project team is not mandatory, doing so can earn the project an additional point. Upon registration, the project team gains access to a suite of digital tools and resources necessary for documentation and compliance.

LEED certification is typically divided into two main phases: design and construction. All supporting documentation must be submitted through the LEED Online platform, where GBCI conducts a thorough review. Each submitted credit is evaluated and marked as either accepted

or denied. If certain credits are initially rejected due to incomplete or insufficient compliance, project teams are allowed to submit clarifications or corrective actions. Once all mandatory prerequisites are satisfied and the desired credits have been successfully achieved, the project becomes eligible for official certification. Additionally, under the LEED Core & Shell system, there is an option to obtain a pre-certification, which serves as a preliminary endorsement of the project's intended sustainable features.

2.6 Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB)

2.6.1 History and Development

The German Sustainable Building Council (DGNB) was established in 2007 and is headquartered in Stuttgart. In collaboration with the Federal Ministry of Transport, Building and Urban Affairs (BMVBS), DGNB developed a holistic framework for evaluating the sustainability of buildings. Unlike systems such as LEED, which originated in the United States, the DGNB certification is tailored specifically to address the environmental, economic, and social priorities relevant to Central Europe. The official launch of the DGNB certification system took place in January 2009, marking the beginning of formal sustainability assessments for buildings in Germany (Hamedani & Huber, 2012).

Germany's decision to develop its own certification system stemmed from the desire to address the limitations of existing international frameworks and to incorporate additional quality standards aligned with national regulations and building practices (Lu Qi, 2010). Germany created its own certification to fill gaps in other systems and add quality requirements that reflect its national standards and regulations. Therefore, DGNB's framework is more compatible with the European Union's Level(s) initiative, which aims to standardize sustainability indicators across member states (Cordero, Melgar, & Márquez, 2019). The DGNB system emphasizes a comprehensive set of evaluation criteria, covering environmental, economic, technical, process-related, and site-specific aspects, along with sociocultural and functional quality. By adopting a holistic approach, the DGNB framework assesses sustainability across the entire lifecycle of a building from planning and construction to operation and eventual deconstruction, thereby ensuring a more integrated and context-sensitive evaluation of building performance.

2.6.2 Structure

The German Sustainable Building Certification is structured around the three foundational pillars of sustainability: ecological, economic, and social dimensions (Hamedani & Huber, 2012). In addition to these, two cross-cutting categories, Technical Quality and Process Quality, have been introduced to address the broader aspects of building performance and management. Each of these categories is broken down into groups of criteria, which in turn are composed of individual criteria relevant to certification. These criteria are assessed using a set of indicators, evaluated either quantitatively or qualitatively. Every criterion is assigned a base value of ten points, but to maintain flexibility and accommodate different building types, a weighting factor ranging from 0 to 3 can be applied based on its significance. As of now, 49 out of a total of 63 criteria are actively used in the certification process (DGNB, 2023).

The six topics are weighted in the following way: Environmental Quality: 25 %, Economical Quality: 25 %, Socio-cultural and functional Quality: 25 %, Technical Quality: 25 %, Process Quality: 10 % and Site Quality: 5 %.



Figure 2.6 DGNB Assessment Categories

2.6.3 Schemes

Since the DGNB system was developed in Europe, it is inherently aligned with European standards, regulations, and construction practices. As such, it offers a variety of certification schemes tailored to different building types and project stages. These include:

1. Existing buildings
2. Interiors
3. New construction
4. Districts

These schemes are further broken down to the following types in Germany. Existing Office, dwelling, healthcare, assembly buildings, hotels, tenant fitout, new offices, residential buildings, education facilities, industry, industrial location, business district, and urban districts.

2.6.4 Certification Levels

The DGNB certification is designed to apply to many types of buildings. Certification can also be awarded in the form of a pre-certificate during the planning phase, which gives project teams a chance to highlight their sustainability goals early on.

	 Platinum	 Gold	 Silver	 Bronze*
Total performance index	80% and higher	65% and higher	50% and higher	35% and higher
Minimum performance index	65%	50%	35%	-- %

Figure 2.7 DGNB Certification Levels

There are certain key features that a project must demonstrate in order to qualify for DGNB certification. These include:

- Taking sustainability criteria into account early in the design process
- Meeting high standards for thermal comfort
- Ensuring good light quality and making effective use of daylight
- Providing strong room acoustics

- Maintaining healthy indoor air quality by using very low-emission building materials
- Choosing environmentally responsible construction materials
- Saving water where possible
- Using an energy-efficient design approach
- Keeping life cycle costs as low as possible

2.6.5 Assessment Categories

Each category in the DGNB assessment is evaluated on its own, and strong performance in one area cannot make up for poor results in another. To receive certification, a project must perform well in all of the individual assessment areas.

Table 2.2 DGNB Criteria Group and Criterion

Categories	Weighting Factor %	Criteria Group	Criterion
Environmental Quality	25	Effects On Global And Local Environment (ENV1)	<ul style="list-style-type: none"> • Climate Action and Energy • Local environmental impact • Responsible resource extraction
		Resource Consumption And Waste Generation (ENV2)	<ul style="list-style-type: none"> • Potable water demand and waste water volume • Land use • Biodiversity at the site
Economical Quality	25	Life Cycle Costs (ECO1)	<ul style="list-style-type: none"> • Life cycle costs
		Performance (ECO2)	<ul style="list-style-type: none"> • Value stability and adaptability • Climate resilience • Documentation

Socio-cultural and functional quality	25	Health, Comfort And User Satisfaction (SOC1)	<ul style="list-style-type: none"> • Thermal comfort • Indoor air quality • Sound insulation and acoustic comfort • Visual comfort • Quality of indoor and outdoor spaces
		Functionality (SOC2)	<ul style="list-style-type: none"> • Barrier-free design
Technical Quality	10	Technical Quality (TEC1)	<ul style="list-style-type: none"> • Quality of the building envelope • Use and integration of building technology • Circular construction • Mobility infrastructure
Process Quality	10	Planning Quality (PRO1)	<ul style="list-style-type: none"> • Quality of project preparation • Ensuring sustainability aspects in tendering and contract allocation • Procedure for urban development and design conception
		Quality Of Construction (PRO2)	<ul style="list-style-type: none"> • Construction site/construction process • Systematic commissioning • Preparation for sustainable use
Site Quality	5	Site Quality (SITE1)	<ul style="list-style-type: none"> • Micro-location • Transport connection • Proximity to objects and facilities relevant to use

Some simple requirements must be met in order to qualify for DGNB certification. These include things like indoor air quality and inclusive design, which are part of the social and functional aspects of a building. In addition, technical areas such as fire safety and sound insulation must follow the legal rules. Each quality section has its own minimum level that must be reached. If even one of them doesn't meet the required standard, the building can't be certified. (Bernardi, Carlucci, Cornaro, & Bohne, 2017).

2.6.6 Certification Process

Before a project starts the DGNB certification process, the builder and the certification team agree on the quality level they aim to achieve. A certified DGNB auditor or planner must be involved during the whole certification and submission process. First, the auditor registers the project online at the DGNB portal. Then, together with the building owner, they set the design goals and put them in writing. The earlier these DGNB criteria are considered in the planning, the more impact they can have on the sustainability of the building.

Several documents are required during the process. These include project registration, proof of construction progress, and the option to apply for a pre-certificate. This pre-certificate is based on design plans and shows the intended certification level. It can be used as a marketing tool during the construction phase. However, it is not a strict requirement for final certification. During construction, regular checks are made. If there are any issues that could affect the expected certification level, they are documented and need to be corrected. After the building is finished, final documents are submitted to DGNB. If all requirements are met, the building is awarded the official certificate either gold, silver, or bronze and a seal or sticker.

2.7 LEED Approach to Sustainable Sites

GBRs help achieve sustainability targets and evaluate their efficiency through defined guidelines and measurement criteria (Ismaeel, 2019). Among these, the LEED system distinctly categorizes Sustainable Sites as a dedicated credit domain aimed at reducing the negative environmental impacts of building development through responsible site selection, ecological protection, and thoughtful outdoor space design.

The importance of proper site selection lies in its ability to reduce buildings' impact on the surrounding environment and improve overall building (Ismaeel, 2021). Recognizing this, LEED emphasizes site assessment as a first step prior to project commencement. This proactive

approach enables project teams to align with sustainability performance targets and pursue higher certification levels (Pham, Kim, Lee, & Ahn, 2020).

LEED begins with a mandatory prerequisite, Construction Activity Pollution Prevention, which ensures projects plan and implement measures to control erosion, sedimentation, and dust during construction. These measures include installing silt fences, sediment traps, stabilized construction entrances, and protecting existing vegetation. The prerequisite requires the inclusion of an erosion and sedimentation control (ESC) plan, conforming to the U.S. EPA Construction General Permit or local equivalents, to be implemented from the pre-construction phase through to project completion. These efforts help safeguard nearby ecosystems and reduce site degradation.

Following this, the Site Assessment credit encourages comprehensive evaluation of natural and social site conditions, such as topography, hydrology, vegetation, soil quality, and public health factors, to guide sustainable site design. This supports developments that are contextually responsive to both environmental and community needs. In addition to project-level factors, LEED considers the broader urban context, rewarding decisions that promote the protection of sensitive land, redevelopment of previously disturbed sites, and infill development with proximity to public transit. At the project level, credits are awarded for actions such as minimizing site disturbance, restoring habitats, and maximizing open space (Ismaeel, 2021).

The Open Space credit specifically promotes outdoor areas that are vegetated or support habitat restoration, with requirements that 30% of the site area be designated as open space and 25% of that be accessible and usable. Such spaces enhance biodiversity, support passive or active recreation, and contribute to occupants' physical and social well-being (USBGC, 2014).

The Sustainable Sites Initiative has developed guidelines to protect and restore site ecosystem services, including credits for water management and habitat preservation (Kabbes & Windhager, 2010). SITES credits, such as Sensitive Land Protection and Protect or Restore Habitat, reward the conservation of natural areas and the use of native vegetation and healthy soils to enhance biodiversity and ecological resilience. Another key focus of LEED's Sustainable Sites category is storm water management. The Rainwater Management credit promotes low-impact development (LID) techniques that restore natural hydrology and reduce the risk of water pollution. Techniques such as bio-retention basins, permeable paving, and green roofs are used to manage runoff at its source.

The Heat Island Reduction credit addresses the challenge of elevated temperatures in dense urban areas by encouraging the use of high-albedo surfaces, vegetated roofs, and shaded hardscapes. Specific compliance paths require treating 50% of non-roof surfaces and 75% of roof surfaces to reduce solar heat absorption. LEED-certified buildings have been found to lower surrounding temperatures by up to 0.35°C, with higher certification levels yielding greater cooling benefits by increased the lowering effect by 0.48 °C (Shin, Kim, Gu, & Kim, 2017).

Complementing this, the Light Pollution Reduction credit protects night sky visibility and wildlife by regulating exterior lighting levels. This is achieved through adherence to BUG ratings (Backlight, Uplight, Glare) or photometric analysis methods that limit light trespass and upward illumination.

The importance of site analysis tools in decision-making is further underscored by research advocating the use of Geographic Information Systems (GIS). GIS has been shown to support more objective and context-sensitive evaluations of LEED credits related to location, transportation, and sustainable sites (Ismaeel, Adel, Dabaieh, & Kenawy, 2016).

Table 2.3 Sustainable Sites Credits

Sub-Categories	Credits
Site assessment	1
Site development- protect or restore habitat	2
Open space	1
Rainwater Management	3
Heat Island Reduction	2
Light Pollution Reduction	1

Overall, proper site selection and strategic planning can significantly affect the sustainability outcomes of a project—beyond just site credits. In fact, up to 63% of total LEED points may be influenced by early decisions related to site location and characteristics, demonstrating the wide-reaching impact of sustainable site development (Ismaeel, 2021). LEED’s site-related strategies not only provide environmental benefits but are also associated with public health co-benefits. Green building strategies have been linked to increased resilience during extreme

heat events and improved urban livability, highlighting the integrative role of site sustainability in promoting both ecological and social outcomes.

2.7.1 LEED Approach to Energy Performance

Buildings use a large amount of energy and are one of the main contributors to environmental problems. They are responsible for about 19% of global greenhouse gas emissions (Pachauri & Meyer, 2014). To make sure there is enough energy for the future, it's important to focus on saving energy. This means that energy-efficient solutions should be part of both the design and construction stages of buildings (González, Díaz, Caamaño, & Wilby, 2011). Energy consumption in buildings remains a central concern in sustainable design due to its direct environmental and economic implications. A major objective of sustainable design and construction is to minimize the adverse impacts of excessive energy consumption (Robichaud & Anantatmula, 2010).

The Energy and Atmosphere category in the LEED system focuses on improving how buildings use energy. It supports energy-saving practices by using tools like energy modeling, performance tracking, system checks, and the use of efficient equipment. The main goal is to lower the amount of energy a building needs for daily operations, make sure electrical systems work properly, and avoid the use of gases that can be harmful to health. (USGBC, LEED v4 BD+C: New Construction, 2019).

The Energy and Atmosphere category has three required items, called prerequisites, which don't carry any points. Along with that, there are six credit areas where up to 33 points can be earned. This means the category makes up about 30% of the total 110 points available in the LEED certification system (Gurgun & Arditi, 2018). Compared to other categories, it has the highest weight, which shows that LEED places strong emphasis on energy as a key factor in measuring a building's sustainability (Ferreira, Pinheiro, Brito, & Mateus, 2023).

The LEED system, particularly under the "Optimize Energy Performance" credit in the Energy and Atmosphere (EA) category, incentivizes reductions in energy cost by awarding points based on performance improvements relative to a baseline defined by ASHRAE Standard 90.1.

LEED uses the ASHRAE 90.1 standard as a reference to set and measure energy efficiency in buildings. This helps create a consistent way to assess energy performance across different

projects. ASHRAE 90.1, developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, sets the basic minimum requirements for how energy should be used in buildings (ASHRAE, 2022). It plays an important role in promoting energy-efficient design and construction, not just in the U.S. but also in projects around the world (Melo, Lamberts, & Versage, 2015).

As part of the certification process, simulation models are often used to show how much energy a building can save compared to a standard baseline model. These simulations help demonstrate the level of efficiency the project is aiming for. According to Meester et al. (2013), using mathematical models and energy simulation tools is widely seen as one of the most reliable ways to understand how a building will perform and to estimate its energy use in advance. Simulations make it possible to take into account a wide range of factors that affect how a building uses and manages energy. They allow for changes in different parameters to see how various strategies might impact energy use. This makes it easier to explore and compare options, helping designers make better decisions to improve performance and meet certification goals.

2.7.2 Simulation of Energy Performance Simulation based on ASHRAE 90.1

In the Energy and Atmosphere category of LEED, both the Minimum Energy Performance prerequisite and the Optimize Energy Performance credit can be met by showing that the proposed building performs better than a reference building. This comparison is usually done through simulation. The reference building's performance is calculated based on the ASHRAE 90.1 standard—using the version currently required by LEED, which is ASHRAE 90.1-2016.

ASHRAE 90.1 sets energy performance rules based on climate zones, which are defined in ASHRAE 169. These zones range from 0 to 8. Zones 0 to 6 are further broken down into A, B, or C, depending on how humid the area is. This system helps adjust energy efficiency standards to fit local weather conditions (Ribeiro, Scolaro, & Ghisi, 2025). The classification is based on heating and cooling degree days (HDD and CDD), which are used to figure out how much heating or cooling a building might need during the year. Briggs et al. (2003) introduced base temperatures of 18.3 °C for heating and 10 °C for cooling in one version of the standard. But the 10 °C base has been questioned, especially when it comes to calculating cooling degree days (CDD). According to Bhatnagar et al. (2018), this cooling base is too low for hot climates.

In such regions, internal heat from equipment and solar gain might not be enough to meet cooling needs, which makes the estimate less accurate particularly for commercial buildings.

Besides the climate-related concerns, ASHRAE 90.1 also uses an energy cost method to evaluate how much energy a building uses. This method takes into account different energy sources and their prices, which brings attention to the financial side of energy use for both owners and users. By doing this, the standard encourages the adoption of more efficient solutions. But there's a drawback: when comparing buildings based only on cost, the type of energy being used isn't always considered (Ribeiro, Scolaro, & Ghisi, 2025). This can result in misleading conclusions about how sustainable or efficient a building really is. A place that uses a lot of energy but gets most of it from renewable sources might actually be more sustainable than a region that uses less energy but relies mostly on fossil fuels. Also, the price of energy depends on where it comes from. In areas with plenty of renewable resources, energy might be cheaper. But in countries that rely heavily on fossil fuels, the cost is usually higher. While focusing on cost savings makes sense in the short term, it can sometimes get in the way of long-term goals like reducing overall energy use (Ribeiro, Scolaro, & Ghisi, 2025).

In a study from California, Kats (2003) compared 33 green commercial buildings to their conventional counterparts and found that certified buildings used 25% to 30% less energy. The research also pointed out that these green buildings had lower peak electricity demand, which adds to their overall energy efficiency. These findings helped build the early belief that getting LEED certification meant a building would perform better in terms of energy use. Ries, Bilec, Gokhan, & Needy. (2006) supported this idea by studying a LEED-certified commercial building near Pittsburgh, Pennsylvania. They found that not only did the building save 30% more energy per square metre, but it also boosted manufacturing productivity by 25%. This example highlights both the environmental and financial benefits of certified buildings.

Hamoda, (2020) also noted that energy savings can come in more than one way directly through energy use itself, and indirectly through things like water conservation and recycling. This shows that LEED has the potential to support wider sustainability goals. In a case study of a residential building in Kuwait, the author found that direct energy use was cut by 40%, indirect energy by 25%, and there was also a noticeable drop in CO₂ emissions.

LEED certification aims to enhance building energy efficiency, but its effectiveness varies. While some studies show LEED-certified buildings consume 25-30% less energy than

benchmarks (Turner & Frankel, 2008), others report mixed results. Dormitories with LEED certification tend to use less energy, while LEED-certified research buildings may consume more (Tilton & Asmar, 2014). Energy performance is influenced by a building's location, its type, and any discrepancies between expected and actual energy use (Ribeiro, Scolari, & Ghisi, 2025). In one case study, a LEED-certified residential used more energy but its occupants reported higher overall comfort than those in non-certified homes. (Vosoughkhosravi, Dixon-Grasso, & Jafari, 2022). The LEED framework's reliance on ASHRAE 90.1 standards may not be optimal for all climates, potentially increasing cooling demands in hot regions (Ribeiro, Scolari, & Ghisi, 2025). These findings suggest that while LEED certification promotes sustainable construction, its energy performance criteria require fine tailoring to account for multiple contexts.

2.8 LEED Approach to Location and transportation

The integration of location of LT considerations is crucial for sustainable building practices. Research shows that a building's location plays a significant impacts for its inhabitants' transportation demands, with suburban locations leading to high emission of greenhouse gas and energy consumption compared to city centers (Bastos, Batterman, & Freire, 2015). Transport plays a key role in sustainable and resilient development. It helps improve access, safety, and efficiency, while also reducing environmental damage and supporting climate goals (Bahale & Schuetze, 2023). Transportation systems, along with communication networks, are essential for strengthening resilience. They allow people to reach basic services in everyday life and provide critical support during emergencies, such as rescue, recovery, and rebuilding efforts (Faturechi & Miller-Hooks, 2024).

Sustainable transport is not only about moving people and goods, it also supports broader development goals. For example, it can help reduce poverty, improve access to work, lower inequality, support women's participation, and cut down on carbon emissions (Bahale & Schuetze, 2023). The way land is used and laid out is closely linked with transport infrastructure, as the physical connections between spaces depend heavily on the surrounding road and transport networks (Bertolini, Clercq, & Kapoen, 2005).

The Location and Transportation (LT) category in the LEED rating system evaluates a project's siting and accessibility, aiming to reduce the environmental effect related to transportation and land use. This category recognizes that where a building is located in relation to infrastructure,

transit networks, and community resources can significantly influence its energy use, emissions, and user behavior over time. Consequently, LEED encourages selecting sites that minimize automobile dependency, promote alternative transportation modes, and integrate with existing urban infrastructure.

The LT category awards points for factors that support compact development, community connectivity, and low-emission transportation. One of the most heavily weighted LT credits is Surrounding Density and Diverse Uses, which can earn a project up to five points. This credit encourages development in already dense urban areas where infrastructure is in place and a variety of daily services like schools, retail stores, and public facilities are within walking distance (USGBC, 2014). By situating buildings in such environments, the credit aims to conserve land, protect farmland and natural habitats, promote walkability, and reduce the vehicle miles traveled by occupants. Ultimately, this fosters healthier lifestyles, lowers emissions, and supports more vibrant and sustainable communities.

Similarly, the Access to Quality Transit credit also worth up to five points rewards developments located within close proximity to frequent and reliable public transportation options, such as bus, rail, or ferry services (USGBC, 2014). The rationale for this credit stems from the recognition that reliable transit access significantly reduces private car usage, which in turn helps to reduce traffic congestion, urban air pollution, and the building's carbon footprint. Projects are assessed based on walking distances between the project and transit stops and the frequency of service, which provides a measurable framework for evaluating how effectively a location supports low-emission commuting.

Supporting non-motorized transport, the Bicycle Facilities credit incentivizes the inclusion of secure bicycle storage and connectivity to existing cycling networks, alongside on-site amenities such as showers and changing rooms for building users (USGBC, 2014). This credit is rooted in both environmental and public health considerations: it reduces dependence on fossil fuel-powered vehicles while encouraging physical activity and reducing lifestyle-related health risks.

To discourage the over-provision of parking, which can promote car use and consume valuable land, the Reduced Parking Footprint credit was introduced. It limits the spaces and number of parking allocated by a project and encourages alternative solutions such as shared parking arrangements and transit incentives (USGBC, 2014). The aim is to mitigate the environmental

harm caused by sprawling parking lots including increased impervious surfaces that exacerbate storm water runoff while nudging users toward more sustainable transportation options.

Lastly, the Green Vehicles credit addresses the environmental burden of vehicle emissions by encouraging the use of fuel-efficient, low emission or electric transport. This is achieved by requiring preferred parking spaces for green vehicles or offering discounted parking rates (USGBC, 2014). Furthermore, projects may include electric vehicle charging stations or alternative-fuel infrastructure. The intent is to shift market behavior and infrastructure development toward cleaner transportation technologies, contributing to long-term climate goals.

Table 2.4 Location & Transportation Credits

Sub-Categories	Credits
Surrounding Density and Diverse Uses	5
Access to Quality Transit	4
Bicycle Facilities	1
Reduced Parking Footprint	1
Green Vehicles	1

Collectively, these credits within the LEED LT category form a comprehensive strategy to reduce transportation-related emissions, enhance land use efficiency, and improve access and mobility for building users. By applying measurable location-based indicators such as density calculations, walking distances, and vehicle impact assessments, LEED provides a transparent and structured methodology for promoting environmentally and socially responsible siting decisions.

2.9 Summary

While LEED has long dominated international discourse on green building certification, the DGNB, as a relatively younger system, has leveraged its position to build upon the strengths and limitations of these established frameworks. The result is a more comprehensive and lifecycle-oriented assessment methodology. DGNB evaluates buildings using a broader and more nuanced set of criteria many of which are more granularly weighted and reflect a multidimensional understanding of sustainability. Notably, detailed comparative analyses

indicate that the DGNB system includes 24 unique criteria not addressed in LEED, while LEED offers only six standalone credits without counterparts in DGNB. In several cases, multiple LEED credits are required to match the scope of a single DGNB criterion.

Furthermore, DGNB's performance-based approach provides greater flexibility during the planning phase, allowing project teams to work within threshold ranges rather than prescribing specific technologies or solutions. This flexibility, however, is strongly dependent on early-stage integration into the design process. When planning and documentation begin early, the practical demands of both systems in terms of implementation, verification, and administrative load can be considered relatively comparable. Yet, such comparability holds most true within the respective national contexts of each system. For instance, applying LEED in Germany imposes additional burdens, as projects must comply with both German norms (e.g., DIN V 18599) and American standards (e.g., ASHRAE 90.1), alongside the requirement to translate all documentation and adopt U.S. customary units.

These observations reinforce the importance of evaluating how LEED criteria perform in situ when applied to buildings certified under alternative national systems like DGNB. The apparent divergence in scope, flexibility, and regional applicability underscores the value of a case-specific, credit-level assessment. Therefore, the present study moves beyond general system-level comparisons and instead focuses on evaluating three critical LEED categories Sustainable Sites, Location & Transportation, and Energy Performance within a Platinum-certified DGNB building in Germany.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Research Approaches

Research methods are the most appropriate strategies for achieving research aims; different types of study have unique technological requirements (Kothari, 2004). Broadly, research methodologies are categorized into quantitative and qualitative approaches, each offering for gathering information, evaluating results, and interpreting findings in line with the study's aims and context.

Quantitative research relies on measuring quantity or amount. It refers to quantifiable events (Kothari, 2004). Quantitative research is based mainly on numerical data. It follows a rigid protocol and necessitates meticulous attention to detail prior to performing the study and collecting data (Pajo, 2017).

On the other hand, qualitative research focuses on qualitative events, which are those that involve or relate to quality or type (Kothari, 2004). Using inductive logic, qualitative research employs procedures such as interviews to gain a thorough insight of the research topic. It often employs loose or novelette questioning designed to elicit wide range of perspectives from participants. However, a planned limited number of persons are usually chosen (Hennink, Hutter, & Bailey, 2020).

Mixed-methods research is a present methodology that combines best aspects of both quantitative and qualitative procedures. Mixed-methods research has been a popular methodology that yields outstanding results (Pajo, 2017). It enables researchers to gather a substantial amount of information on a wide range of issues.

3.2 Research Type

This study uses both qualitative and quantitative methods to assess the sustainability performance of the DGNB Platinum–certified Beiersdorf Troplo Kids daycare center in Hamburg, Germany. Quantitative methods were employed to collect and analyze data on measurable factors, including transit stop distance, land use intensities, and open space ratios. These number-based analyses enabled comparative analysis along systemic lines concerning the LEED v4 Building Design and Construction (BD+C) School requirements, facilitating an impartial judgment regarding the level of the building's compliance and performance. Additionally, qualitative methods were employed to consider contextual and environmental factors that impact sustainability, such as site conditions, landscape factors, and urban

connectivity. However, due to data limitations, energy performance modeling could not be independently conducted. Instead, performance assessment relied on verified architectural and technical documents.

Combining the two approaches enhances the credibility of the findings by reconciling statistical analysis with observational findings and reducing potential biases. This mixed-methods research enabled an integrative examination of how the DGNB-certified structure fulfills LEED specifications, providing pragmatic guidelines for improving sustainable construction methods within the German and international spheres.

3.3 Research Design

A case study method was chosen for this study to allow a detailed analysis of a real-world building. The Beiersdorf Troplo Kids daycare center located in urban Hamburg has been certified by the DGNB with the German Quality Seal for Sustainable Building in Platinum (Beiersdorf).

Researchers can preserve the comprehensive and significant elements of real-world event , including small-group behavior, individual life cycles, organizational and management processes, neighborhood development, school performance, international interactions, and industrial maturation, by using the case study technique. Some case study research goes beyond the definition of qualitative research by combining quantitative and qualitative evidence (Yin, 2019).

Case studies can demonstrate specific subjects within an examination, again in a descriptive manner (Yin, 2019). By focusing on a single, information-rich example, this research was able to explore in detail how DGNB and LEED criteria are applied. The Beiersdorf Troplo Kids daycare center project allows for a comparison of the system's requirements (e.g., transit proximity, habitat protection, energy performance) without the confounding variables introduced by multiple case contexts. In doing so, the case study approach offers both the descriptive richness and analytical depth required to uncover nuanced synergies and gaps between the German DGNB framework and the international LEED v4 BD+C standard.

The Beiersdorf Troplo Kids daycare center was purposively selected as the case study for this research because it meets several critical criteria that support an in-depth, comparative analysis of DGNB and LEED frameworks.

Case Selection Criteria: The case was chosen based on:

1. **DGNB Platinum Certification:** Serves as an exemplar of advanced sustainable design, making it an “extreme” case whose performance under LEED v4 BD+C can be rigorously tested.
2. **Urban Context:** Located in a high-density, mixed-use setting, essential for assessing Location and Transportation and Sustainable Sites criteria.
3. **Data Availability:** The project’s documentation, including the architectural report, materials used, and performance reports, ensures reliable quantitative and qualitative data for spatial analyses and energy performance, thereby enhancing the study’s validity.
4. **European Relevance:** The building was characterized by the highest architectural, ecological, and technical standards. It was constructed according to the guidelines of the German Sustainable Building Council (DGNB), which reflects the regulatory and climatic conditions common to many German and European projects (Beiersdorf).

For assessing Energy Performance, the inability to access detailed technical drawings or perform site measurements limited the feasibility of quantitative modeling. As a methodological adaptation, secondary data sources primarily architectural reports, façade specifications, and sustainability disclosures by the design team were utilized to conduct a qualitative assessment aligned with LEED energy performance indicators. While this does not replace simulation, it still provides valuable insights into how the building design supports thermal efficiency.

3.4 Data Collection

This study employs two data-gathering methods: primary and secondary data, both of which will be analyzed statistically (Naoum, 2012). Data collection integrated both primary and secondary research to provide a thorough treatment of suitable and pertinent information. Primary data were gathered through site observation, which provided first-hand exposure to the physical environment and sustainability of buildings. However, due to a lack of permission for site photography or direct façade measurements, the primary data are limited; site observations were replaced by documented descriptions from the architect's report. All direct site-based primary data collection is constrained; this limitation is explicitly acknowledged and addressed.

In contrast, secondary data sources included official DGNB and LEED technical manuals for criteria definitions, field observation, desktop research, reports published by building architects

and site drawing for spatial and material analysis, and publicly available geospatial (or GIS) applications/platforms or web mapping services/clients like Google Earth, Geoportal Hamburg, OpenStreetMap, Hamburg Verkehrsverbund (hvv), etc. to evaluate environmental sensitivities. Furthermore, related scholarly literature and existing research studies were examined to put findings into perspective against the broader body of literature related to sustainable building evaluation.

Furthermore, project data was extracted from the architect's firm, Kadawittfeldarchitektur's project report, and the daycare's website to verify design components, programmatic requirements, and sustainability initiatives. Information was also extracted from the corporate parent and project commissioning client, Beiersdorf AG, to understand the organizational sustainability goals and corporate conditions that inform the Troplo Kids daycare center project.

Due to limited access to detailed primary data such as façade measurements and spatial geometry, energy performance simulations could not be conducted directly by the researcher. This constrained the depth of analysis for Energy Performance and related Research Questions. However, a qualitative and document-based analysis of energy-relevant features (e.g., insulation type, window type, material specifications) was conducted using secondary data. Instead, the analysis of energy-related parameters such as thermal conductivity (U-values), wall thickness, window size, glazing type, and window-to-wall ratio (WWR) relied on verified secondary data obtained from the architectural report and technical documentation provided by the design firm.

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3.5 Analytical Framework

This study adopts the LEED v4 for Building Design and Construction (BD+C) Schools as the external reference framework to assess selected aspects of the Beiersdorf Troplo Kids daycare center, a project already certified with the highest DGNB Platinum rating.

It is essential to note that the macro-areas of LEED and DGNB are not defined in the same manner, rendering a direct system-to-system comparison methodologically inappropriate. As shown in Figures 3.1 and 3.2 (from the DGNB and LEED system structures), LEED organizes its evaluation through a credit-based point system (total of 110 points) across discrete categories. At the same time, DGNB uses a percentage-based weighting model grouped into six overarching quality sections (e.g., Environmental, Economic, Site Quality).

For this reason, the methodology of this study does not attempt to align or map individual LEED credits to DGNB categories. Instead, it evaluates the project solely through selected LEED criteria while acknowledging the broader DGNB certification that has already been awarded.

This methodological decision ensures both clarity and transparency and avoids the risk of misaligned or oversimplified system equivalency.

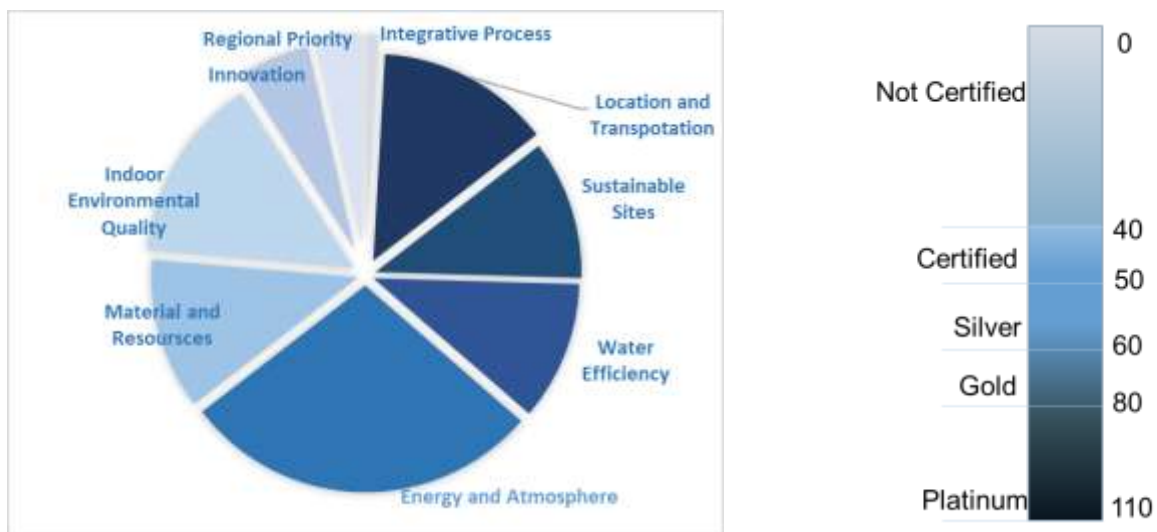


Figure 3.1 Levels and Areas of Certification in LEED v4 BD+C School (Author)

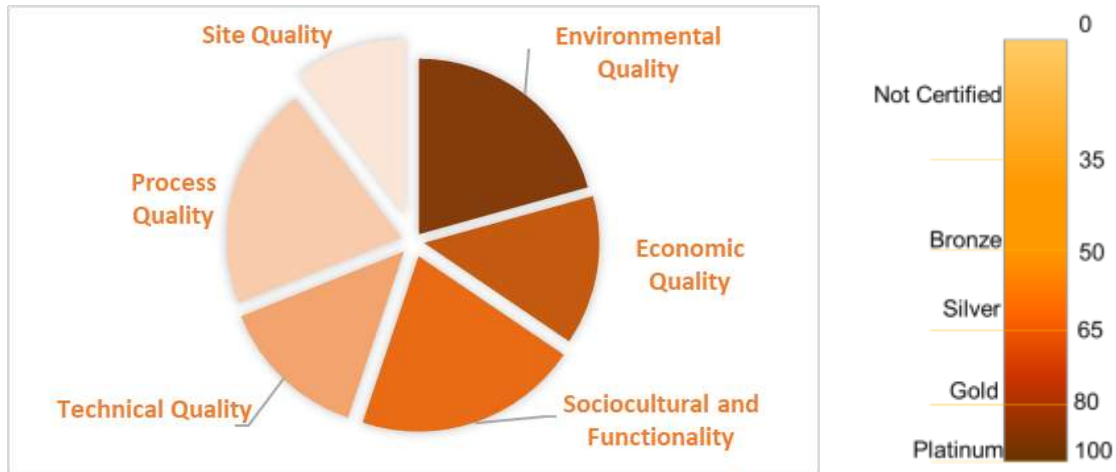


Figure 3.2 Levels and Areas of Certification in DGNB (Author)

To address the structural mismatch between the LEED and DGNB certification systems, this study does not attempt a comprehensive comparison of the two systems. Instead, it adopts a focused, credit-level approach by applying a carefully selected subset of LEED v4 BD+C School credits, totaling 18 points, to the DGNB Platinum-certified Beiersdorf daycare center Troplo Kids building.

Drawing inspiration from the methodology of Asdrubali et al. (2015), this approach uses LEED as an evaluative framework to assess specific aspects of the building's sustainability performance. Rather than pursuing a full LEED certification, the study conducts a partial credit analysis, targeting categories that are thematically aligned with the DGNB system and highly relevant to the case context, namely, Sustainable Sites and Location and Transportation.

These credits fall within the LEED categories of Sustainable Sites and Location & Transportation, where measurable criteria (e.g., transit proximity, open space ratio, habitat protection) enable objective assessment, as shown in Tables 3.1 and 3.2.

Table 3.1 Selected LEED Categories along with Credit Points (Author)

LEED Category	Credit IDs	Credit Title	Points
Location and Transportation	Surrounding Density	LTc3	5
Location and Transportation	Access to quality Transit	LTc4	4
Location and Transportation	Bicycle Facilities	LTc5	1
Location and Transportation	Reduced Parking Footprint	LTc6	1
Location and Transportation	Green Vehicles	LTc7	1
Sustainable Sites	Site Assessment	SSc1	1
Sustainable Sites	Site Development protect or restore habitat	SSc2	2
Sustainable Sites	Open Spaces	SSc3	1
Sustainable Sites	Heat Island Reduction	SSc5	2

Table 3.2 Selected LEED v4 Categories Total Credit Points (Author)

Macro Area	LEED Credits	Max Possible Points
Location and Transportation	LTc3+LTc4+LTc5+LTc6+LTc7	12
Sustainable Sites	SSc1+SSc2+SSc3+SSc5	6
Total Points		18

3.6 Mini-Rating Scale

Since the building is already DGNB Platinum certified, this research does not attempt to replicate or reinterpret the DGNB assessment. Instead, it utilizes a mini-rating scale and a normalized LEED framework as a diagnostic tool to examine how a high-performing German building aligns with international sustainability criteria.

$$\text{Normalized Score (\%)} = \frac{\text{Points Achieved}}{18} \times 100$$

The normalized result was then compared against LEED normalized certification thresholds to assign a LEED-equivalent rating band within this 18-point subset. LEED normalized certification levels were interpreted as shown in Table 3.3 and Figure 3.3.

Table 3.3 Mini-Rating Scale Criteria and Levels (Author)

LEED Band	Mini Rating Scale (pts)
Not-Certified	6.4
Certified	6.5
Silver	8.2
Gold	9.8
Platinum	13.1

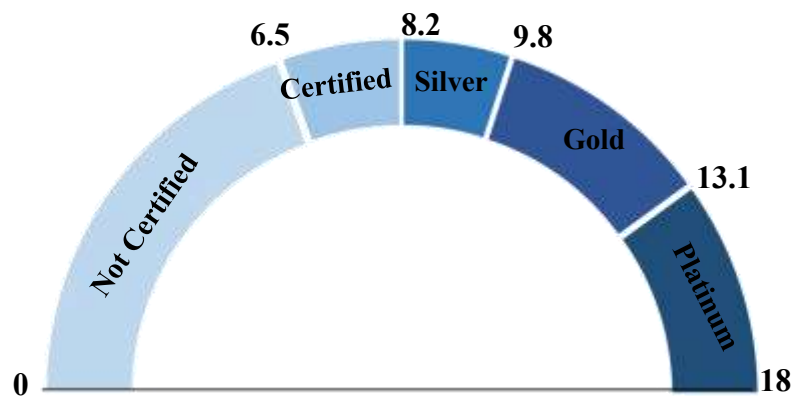


Figure 3.3 Mini-Rating Scale Band (Author)

This adapted certification banding allows the performance of the Beiersdorf daycare center Troplo Kids building to be interpreted through the lens of LEED, even though full certification was not pursued. The approach offers insight into how a DGNB-certified project might fare under an international sustainability framework.

Although a full simulation was not possible, Energy Performance, particularly those referencing building envelope design, were reviewed using available documentation and were backed by literature review, GEG (Gebäudeenergiegesetz) as Building Energy Act and EnEV (Energieeinsparverordnung) as Energy Saving Ordinance.

CHAPTER 4 CASE STUDY

4.1 Building Overview

Beiersdorf Troplo Kids Daycare Center sits on Beiersdorf AG's inner-city campus in Hamburg-Eimsbüttel, Germany, next to a small green space. This two-story building features a simple rectangular form, organized around a central double-height multipurpose room that serves as both a play and meeting space. Its design, which echoes the look of an old apothecary cabinet, uses shelf-like façades to create a bright, airy interior. Floor-to-ceiling windows flood the rooms with light perfect for play and learning—while the bold, colored frames on the outside help children identify their group areas. Inside, these same frames become play elements platforms, boxes, and seating inviting kids to climb, sit, and explore, allowing their imagination to flourish. (kadawittfeldarchitektur, 2015).



Figure 4.1 Troplo Kids Daycare Center, Front View (kadawittfeldarchitektur, 2015)

The colored frames integrated into the east- and west-facing facades extend into interior spaces, serving as comfortable seating and resting spots. The vivid features, visible both inside and out, define the structure and serve as a point of reference for the kids. The large-scale window designs are also intended to create a bright and transparent atmosphere within the spaces, enabling adequate daylight to penetrate (kadawittfeldarchitektur, 2015).

4.2 Color coordination

Children’s artwork, along with carefully chosen materials and furniture, brings constant color to the interior. The main surfaces wood floors, white-plaster walls, and white acoustic ceiling panels are kept neutral so that the bright colors of the exterior frames stand out inside. For example, each classroom door and its nearby coat cubbies are painted to match the color of its outside frame, making it easier for children to find their way (see Figure 4.2). Each room also has a custom play structure shaped like a large building block. These structures include raised platforms, a small play kitchen, slides, cozy hideaways, climbing parts, and bridges to encourage children to explore and see their space from different angles. (kadawittfeldarchitektur, 2015).



Figure 4.2 Troplo Kids Daycare Center Color Coordination (kadawittfeldarchitektur, 2015)

4.3 Design and Construction

The two-storey daycare is laid out for easy flow and accessibility. On the ground floor there is crèche, utility rooms, and a large multipurpose hall. Wide benches and a staircase in the hall lead up to the first floor, which contains another crèche, two kindergarten rooms, a kitchen and dining area, a workshop, a preschool activity space, and a staff room (see Figures 4.3 and 4.4). An elevator connects both levels, ensuring full accessibility. The central double-height hall acts as the building’s heart—linking all areas, hosting community events, and doubling as an indoor play area on rainy days (kadawittfeldarchitektur, 2015).

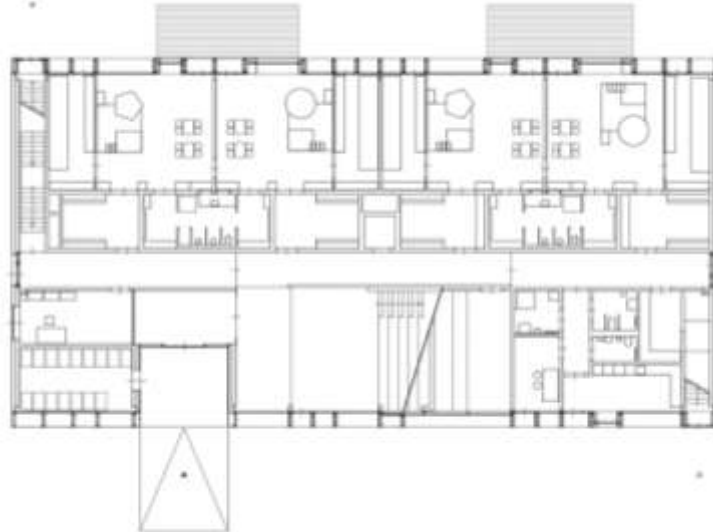


Figure 4.3 Troplo Kids Daycare Center; Ground Floor Plan (kadawittfeldarchitektur, 2015)

All interior components were designed to eliminate sharp corners or edges, underscoring the emphasis on child safety and ergonomic comfort in the building's programmatic layout (kadawittfeldarchitektur, 2015).

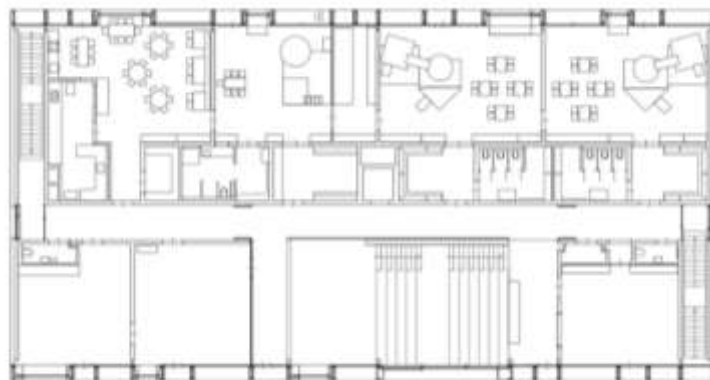


Figure 4.4 Troplo Kids Daycare Center; First Floor Plan (kadawittfeldarchitektur, 2015)

4.4 Sustainability

Troplo-Kids, a children's daycare facility in Germany, received the DGNB Platinum designation for a kindergarten project in November 2014. DGNB awarded Troplo Kids Daycare Centre an 85.5% total performance index, as shown in Figure 4.5.



Figure 4.5 Troplo Kids Daycare Center, Certification Result (DGNB, Beiersdorf AG Daycare Center, Hamburg, 2014)

At the end of 2011, the project team set binding DGNB Pre-Check performance targets and captured them in a detailed specification document. These targets were validated through design-phase simulations, and every selected material was tested and verified to satisfy DGNB certification requirements. (kadawittfeldarchitektur, 2015).

CHAPTER 5 EVALUATION OF TROPLO KID – TRANSPOTATION, SITE AND ENERGY PERFROMANCE

5.1 Overview of Selected LEED Credits

This chapter presents an evaluation of the Beiersdorf daycare center, Troplo Kids, a DGNB Platinum-certified building, against selected LEED v4 BD+C School credits and Energy Performance. The purpose is to assess how the building, originally designed and certified under the DGNB framework, would perform under equivalent LEED sustainability metrics and its energy performance. A total of nine credits were selected from the categories of Location and Transportation (LT) and Sustainable Sites (SS), representing a subset of 18 possible points. Each credit is analyzed based on site-specific data, architectural documentation, and performance criteria outlined in the LEED standards.

5.2 Location and Transportation

5.2.1 Surrounding density and diverse uses (LTc-3)

5.2.1.1 Intent of Credit

This initiative aims to conserve land resources and safeguard both farmland and wildlife habitats by encouraging development within areas that are already supported by existing infrastructure. It promotes walkability and enhances transportation efficiency by supporting compact, connected urban forms, thereby reducing reliance on private vehicles and minimizing overall vehicle travel distances. (USGBC, Surrounding density and diverse uses (Schools), 2014)

5.2.1.2 LEED Criteria

LEED credit criteria and thresholds were referenced directly from the USGBC (2014) which are as follow;

Option 1: Surrounding Density (2–3 Points)

The surrounding density calculation was based on the combined density method, which considers the total gross floor area (GFA) of all buildings, both residential and non-residential, within a 400-meter radius of the project site, as shown in Figure 5.1.

Physical education spaces that are part of the project site

Combined density	Separate residential and nonresidential densities		Points BD&C (except Core and Shell)	Points BD&C (Core and Shell)	Points ID&C
	Square meters per hectare of buildable land	Residential density (DU/hectare)			
5,050	17.5	0.5	2	2	3
8,035	30	0.8	3	4	6

Figure 5.1 Points for Average density within 400 radius of the project (SI Units) (USGBC, Surrounding density and diverse uses (Schools), 2014)

Option 2: Access to Diverse Uses (1–2 Points)

In addition to density, the accessibility of diverse services and community functions was assessed within an 800-meter walking distance of the project’s main entrance. This analysis aimed to determine compliance with LEED’s Diverse Uses credit, which promotes walkable access to a mix of everyday destinations.

The qualifying uses represented at least three of the five required categories from LEED under Access to Diverse Uses credit, including:

1. Community anchors include public schools, libraries, etc.
2. Civic and community facilities include parks, playgrounds, etc.
3. Services: hair salon, bank, etc.
4. Community-serving retail: pharmacy, bookstore etc.
5. Food retail: supermarket, bakery etc.

This mix of uses meets the highest threshold under Option 2, earning the project 2 LEED points for walkable access to eight or more diverse uses across five categories.

5.2.1.3 Measured Performance

A detailed spatial analysis was conducted for the daycare facility. This credit encourages site selection in areas with existing infrastructure, high density, and access to a variety of amenities, thereby promoting walkability and reducing vehicle dependence.

The analysis involved calculating the total gross floor area (GFA) of buildings within a 400-meter radius around the daycare project site, utilizing geospatial tools provided by the Hamburg Geoportal, specifically the ALKIS-Express (farbig) layer for accurate building data, as shown in Figure 5.2.

The surrounding built environment comprises a mix of residential and commercial structures, ranging in height from single-story to eight-story buildings, with some including basement levels. The area measurement tool within the geoportal was used to trace and calculate the footprint of each building manually. These footprints were then multiplied by the estimated number of stories, derived from visual observation and available building information, to more accurately estimate the vertical density.

The analysis estimated a total gross floor area of approximately 2,326,306 square meters within the 400-meter radius. The total land area was 50 hectares, sourced from the Hamburg Geoportal as shown in Figure 5.2. After excluding non-developable areas such as roads, parks, and open surface parking lots, the buildable land area was determined to be 39.23 hectares. These values indicate a relatively high-density urban environment, aligning with the credit requirements and supporting the daycare's sustainable location strategy.

Accordingly, the combined density was calculated as:

$$\text{Combined Density} = \frac{\text{Total GFA}}{\text{Buildable Land Area}} = \frac{2,326,306 \text{ m}^2}{39.23 \text{ ha}} = 59,286 \text{ m}^2 / \text{ha}$$

This result significantly exceeds the maximum threshold of 8,035 m²/ha established in LEED for BD&C. This level of density meets the threshold for the maximum number of points under the ID&C rating system and qualifies for 3 points under Building Design and Construction (BD&C).

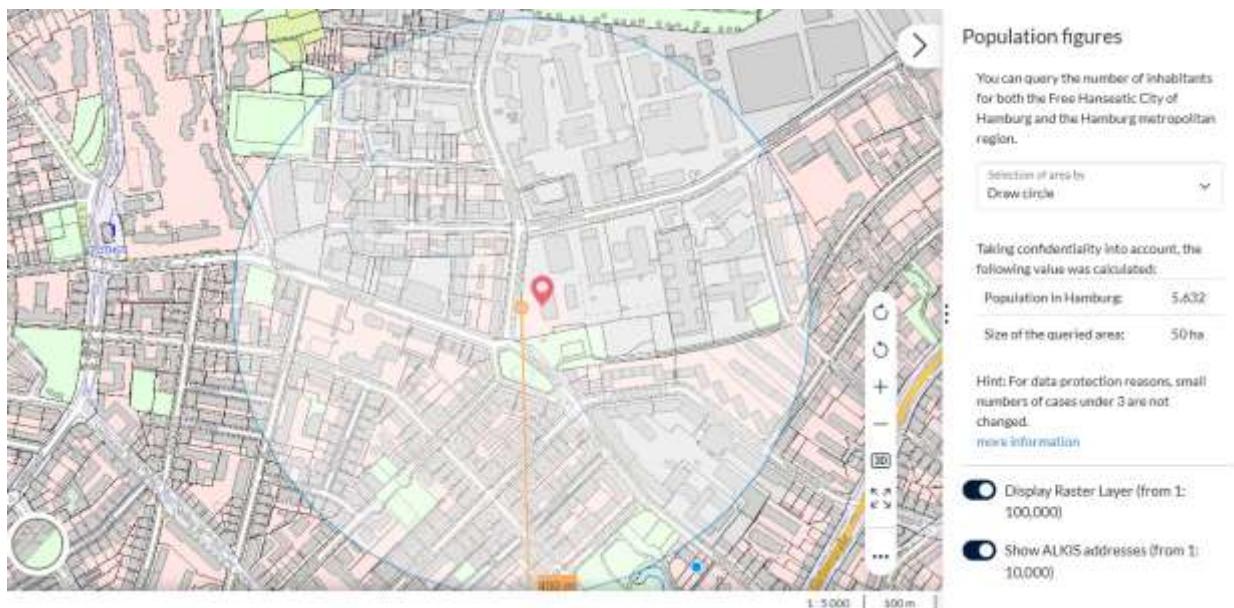


Figure 5.2 Geoportal Hamburg ALKIS-Express (farbig) layer within 400 meters' radius (HamburgGeoportal, 2025)

For diverse uses, OpenStreetMap, Hamburg Verkehrsverbund (HVV), and Google Maps were utilized, and eight publicly accessible uses were identified within the required distance. In compliance with LEED restrictions, no more than two uses per category were counted, and the project's primary use (childcare/education) was excluded.

The project demonstrated compliance by identifying a total of nine publicly accessible uses within an 800-meter walking distance from the main entrance, distributed across four distinct LEED-defined use categories: Civic and Community Facilities, Services, Community-Serving Retail, and Food Retail (Lidl) as shown in Figure 5.3.



Figure 5.3 Lidl, a community services retail within 800 meters of Project Site (Author)

As per LEED guidelines, no more than two uses per category were counted, and the building's primary use was excluded from the calculation. As illustrated in Table 5.1, the variety and proximity of these destinations confirm that the project satisfies the criteria for the maximum available credit under this option, thereby earning 2 LEED points for promoting walkability and access to essential services.

Table 5.1 Diverse uses within 800 meters of Project Site (Author)

Category	Name	Type
Food Retail	Lidl	Supermarket
	Aldi	Supermaket
Community Serving Retail	Malteser Apotheke	Pharmacy
Services	Kim's Kitchen - laotisches Bistro	Restaurant
	Hatari Pfälzer Stube	Restaurant
	Gym Hamburg Trainingsraum - EMS Training Eimsbüttel	Gym
Civic and Community Facilities	Kath. Kirchengemeinde St. Bonifatius	Church
	Eimsbütteler Park	Park
	Deutsche Post Filiale 403	Post Office
	Schule Lutterothstraße	Elementary School

The Troplo Kids Daycare project earns five LEED points under the Location and Transportation (LT) category. It secures three points for Surrounding Density with a high combined density of 59,286 m²/ha, indicating a highly urbanized setting. An additional two points are awarded for Access to Diverse Uses, with nine qualifying destinations across four categories within 800 meters, promoting walkability and connectivity, as shown in Table 5.2.

Table 5.2 Points earned by Beiersdorf daycare center "Troplo Kids" in Surrounding density and diverse uses (Author)

Criteria ID	Points	Requirement	Earned Value	Points Earned
Surrounding density and diverse uses-LTc-3	3	8,035 m ² /ha	59,286 m ² /ha	3
	2	8 use type per category	9 use type per category	2

5.2.2 Access to quality Transit (LTc4)

5.2.2.1 Intent of Credit

This credit aims to promote development in locations well-served by multimodal transportation options, thereby encouraging a reduction in private motor vehicle dependency and a decrease in greenhouse gas emissions. (USGBC, Access to quality transit, 2014)

5.2.2.2 LEED Criteria

According to the USGBC (2014), for LTc4 Access to Quality Transit projects may earn between 1 and 4 points by locating a functional building entrance within 400 meters of a bus, streetcar, or rideshare stop or 800 meters of a bus rapid transit, light rail, heavy rail, commuter rail, or ferry terminal.

To qualify, the selected transit routes must provide a minimum number of weekday departures in one direction, ranging from 72 trips for 1 point to 360 trips for 4 points, as shown in Figure 5.4.

Weekday trips	Points
72	1
144	2
360	4

Figure 5.4 Transport modes (bus, rail, ferry, or streetcar), minimum daily transit service requirement (USGBC, Access to quality transit, 2014)

The qualified transit should fulfill the following points.

1. Each qualifying transit route must offer paired directional service, meaning it operates in both directions (e.g., inbound and outbound).
2. When calculating total weekday service frequency, only trips in one direction are included in the assessment.
3. If a single transit route includes multiple stops within the required walking distance, the project may count trips from only one of those stops to avoid duplication in the calculation.

5.2.2.3 Measured Performance

The Troplo Kids daycare center meets the requirements of LEED v4 BD+C LT Credit 4 – Access to Quality Transit by providing exceptional access to frequent public transportation services. A total of three qualifying transit stops were identified within the required walking distance of the project's main functional entrance: two bus stops (Sorthmannweg and Wiesingerweg, located within 250 meters) and one U-Bahn station (Lutterothstraße, located within 750 meters), as shown in Table 5.3 and Figure 5.5.

Table 5.3 Transit Stops within 800 meters of Project Site (Author)

Stop Name	Route Number	Transit Type	Distance from Site (m)	Weekdays	Timings	Paired Route?	Weekday Trips (1 Direction)
Sorthmannweg	Bus 181	Bus	150m	Mon/Tue/Wed/Thru/Fri	00:00-23:00	Yes	84
Wiesingerweg	Bus 30	Bus	250m	Mon/Tue/Wed/Thru/Fri	00:00-23:00	Yes	109
Lutterothstraße	U2	U-Bahn	750m	Mon/Tue/Wed/Thru/Fri	00:00-23:00	Yes	220
Total Trips (1 Direction)							381

All three routes offer paired service, operating in both directions throughout the weekday schedule.



Figure 5.5 Transit Stop near Troplo Kids Day Care Center (Author)

Based on weekday timetables provided by the HVV Hamburg transit authority, the cumulative number of weekday trips in one direction from these routes amounts to 381, thereby surpassing the LEED threshold of 360 trips required to earn the maximum 4 points for this credit as shown in Table 5.4. Each route was counted only once, with no duplication of stops along the same transit line, in complete alignment with LEED's evaluation methodology.

The daycare center satisfies the intent and technical thresholds for LT Credit 4 by demonstrating strong multimodal connectivity. With more than 360 one-directional weekday trips from multiple unique transit routes within walking distance, the project earns the full 4 points under LEED v4 BD+C LT Credit 4 Access to Quality Transit.

Table 5.4 Points earned by Troplo Kids daycare center in Access to Quality Transit (Author)

Criteria ID	Points	Required Weekday Trips (1 Direction)	Earned Value	Points Earned
Access to quality Transit – LTc4	4	≥360	381	4

5.2.3 Bicycle facilities (LTc5)

5.2.3.1 Intent of Credit

The aim is to encourage sustainable transportation practices by promoting bicycle use as a viable alternative to motor vehicle travel. Additionally, it aims to support public health by facilitating opportunities for regular physical activity through the provision of safe, convenient, and well-integrated bicycling infrastructure for both utilitarian and recreational purposes (USGBC, Bicycle facilities, 2014).

5.2.3.2 LEED Criteria

According to USGBC (2014), credit under the LEED v4 Location and Transportation category is worth 1 point. Projects must be located within 200 yards (180 meters) of a connected bicycle network that serves at least 10 diverse uses or a major transit stop within a 3-mile radius. Dedicated bike lanes must extend to the edge of the school property without barriers. For facilities, projects must provide long-term bike storage for at least 5% of regular occupants (excluding students grade 3 and below) and showers/changing rooms based on staff occupancy, with specific distance and access requirements, as shown in Table 5.5.

Table 5.5 Requirement for Bicycle Facilities Credits (USGBC, Bicycle facilities, 2014)

Category	Requirement
Bicycle Network Proximity	Within 200 yards (180 meters) of a network that connects to:
	10 diverse uses OR A major transit stop
	All destinations must be within 3 miles (4,800 meters) of the project boundary
Bicycle Lane Continuity	Dedicated lanes must extend to end of school property with no barriers (e.g., fences)
Long-Term Bike Storage	Storage for $\geq 5\%$ of regular building occupants (excluding students grade 3 and below), minimum 4 spaces per building
	Storage must be within 100 feet (30 meters) walking distance of a main entrance
Showers and Changing Room	1 shower for first 100 staff (excluding all students)
	1 shower per additional 150 staff (excluding all students)

5.2.3.3 Measured Performance

The Troplo Kids daycare center meets most of the criteria outlined under LEED v4 BD+C LT Credit 5 Bicycle Facilities, with partial compliance achieved. The project provides four long-term bicycle storage spaces, the LEED minimum requirement, even though only two were needed to satisfy the 5% threshold for 28 staff members, as shown in Table 5.6. Also, the bike racks are located within the project site entrance, thus satisfying the requirement for bicycle storage to be within 30 meters of the main entrance. LEED requirement for accessibility; therefore, this aspect of the credit is satisfied.

Table 5.6 Points earned by Troplo Kids daycare center in Bicycle Facilities (Author)

Credit ID		Points		Component	Requirement	Measured Performance	Points Earned	
Bicycle Facilities LTC5	A	1	0.5	Bicycle Network Proximity	Bicycle storage or building entry must be within 180 meters of a bicycle network .	140 meters	0.25	1
					Network must connect to ≥10 diverse uses OR a transit station (bus rapid transit) within 4,800 meters cycling distance.	Connects to 3 Bus stops and U-bahn stop within a proximity of 850 meters		
				Bicycle Lane Continuity	Bicycle lanes must extend at least to the edge of the school property without physical barriers .	yes		
	B	1	0.5	Long-Term Bicycle Storage	Provide ≥5% of regular building occupants with long-term storage, with a minimum of 4 spaces per building.	28 teachers 5% of 28 is 1.4 but the minimum Requirement is 4 spaces	0.25	
					Must be located within 30 meters of a main entrance and be easily accessible.	4 spaces for bike storage		
						Bike storage is within the project site		
			Showers and Changing Rooms	Provide 1 shower per 100 regular occupants , plus 1 additional shower for every 150 additional occupants (excluding students under grade 3).	(Does not apply) Showers are not required where occupants are not expected to cycle (e.g., in daycare facilities). Troplo Kids offers a second home to children aged nine weeks to six years. The total staff is less than 100	0.25		

The project is situated within 140 meters of a local bicycle network, which connects to three bus stops and a U-Bahn station within approximately 850 meters, thereby fulfilling the requirement for bicycle network proximity, as shown in the Figure 5.6. Additionally, dedicated bike lanes extend to the edge of the school property without physical barriers, further supporting LEED criteria for bicycle lane continuity.



Figure 5.6 Bicycle Lanes near Troplo Kids daycare center Premises (Author)

Showers and changing facilities are not provided; however, this is considered an exemption for facilities such as daycare centers, where building occupants (e.g., early childhood educators) are not typically expected to commute by bicycle. As the total number of staff is less than 100, only one shower would have been required if applicable.

The project meets the requirements for bicycle network proximity, lane continuity, and long-term bike storage quantity, as well as the proximity requirement for bike rack placement (within 30 meters of a main entrance). Shower facilities are justifiably exempt due to the building type. As a result, the project earns 1 out of a possible 1 point for LEED LTc5 Bicycle Facilities.

5.2.4 Reduced Parking Footprint (LTc6)

5.2.4.1 Intent of Credit

This credit aims to mitigate the environmental impacts of parking infrastructure, including reducing automobile dependency, minimizing land use for vehicle storage, and limiting stormwater runoff associated with impervious parking surfaces (USBGC, Reduced Parking Footprint, 2014).

5.2.4.2 LEED Criteria

According to USBGC (2014), the project must meet specific requirements to qualify for the credit. According to LEED, projects must not include more parking than what is required by the local code. Additionally, projects must provide parking at a reduced capacity, based on the base ratios recommended by the Parking Consultants Council, as outlined in the Institute of Transportation Engineers' Transportation Planning Handbook, 3rd edition (Tables 18-2 to 18-

4), as shown in Figure 5.7. This requirement aims to reduce land consumption, limit automobile dependence, and encourage the use of sustainable transportation options.

Code	Use	Period	ITE Parking Generation (Third Edition, 2004)						POC Recommended Zoning Ordinance Provisions (2006)		
			# Spaces	Coefficient of Variation	K ²	Parking Gen. Ratio to Peak Hour of Observed				LPI	
						33rd Percentile	Average	66th Percentile			
520	Elementary School	Weekday	6	90%	0.16	0.28	0.28	0.28	Students	Higher of 0.25/children or gym ratio and 0.25/children	
530	High School	Suburban Weekday	6	10%	0.08	0.23	0.26	0.28	Students	Higher of 0.25/children or gym ratio and 0.25/children	
		Urban Weekday	3	60%	0.06	0.06	0.06	0.13	Students		
540	Junior/Community College	Suburban Weekday	7	95%	0.05	0.17	0.21	0.25	School Population	Parking study prepared for institution	
540	University/College	Suburban Weekday	8	10%	0.09	0.30	0.30	0.34	School Population		
		Urban Weekday	3	15%	0.17	0.17	0.17	0.19	School Population		
550	Church	Sunday	11	36%	0.41	0.44	0.44	0.51	Members	0.25/seat	
		Sunday	18	37%	0.40	0.41	0.44	0.50	Members		
		Sunday	11	71%	3.91	3.69	3.61	3.84	113.70	700 sq. ft. (GFA)	0.25/occupied student
565	Day Care Center	Weekday	27	33%	0.73	0.18	0.24	0.24	Students		
		Weekday	37	32%	0.82	1.14	1.35	1.78	Employees		
			44	40%		1.96 (1.74)	3.40 (3.18)	3.86 (3.75)	100 sqm (347 GFA)		

Figure 5.7 Institute of Transportation Engineers' Transportation Planning Handbook, 3rd edition (LEED, 2014)

LEED differentiates projects based on their location:

Case 1: Projects that have not received points under Access to Quality Transit or Credit Surrounding Density and Diverse Uses are required to reduce the base ratios by 20%.

Case 2: A reduction of 40% from the base ratios is required for projects that receive one or more points under either LT Credit Access to Quality Transit or LT Credit Surrounding Density and Diverse Uses.

5.2.4.3 Measured Performance

The project, Troplo Kita, has received five credits for Surrounding Density and Diverse Uses. Therefore, the project qualifies under Case 2. The number of parking spaces permitted under LEED is calculated by reducing the base parking total by the required percentage (40%). For Troplo Kita, a licensed daycare facility with a capacity of 100 children, as outlined in the Institute of Transportation Engineers Transportation Planning Handbook, 3rd Edition, the appropriate base parking ratio is 0.3 parking spaces per licensed child. The calculations are as follows;

$$100 \times 0.3 = 30 \text{ spaces}$$

$$40\% \text{ reduction} = 30 \times 0.60 = 18 \text{ spaces (LEED maximum allowed)}$$

It also mandates that 5% of the total allowed parking (after reduction) be reserved for carpool or shared-use vehicles.

$$5\% \text{ of } 18 = 0.9 = 1 \text{ carpool space required}$$

The daycare is a project of Beiersdorf AG; it relies on shared access to Beiersdorf's Parkpalette, a multi-level parking structure with approximately 500 spaces used by company employees. Beiersdorf headquarters employs approximately 2,500 staff, while Troplo Kita has 29

employees and serves around 100 children (Beiersdorf, 2025). Based on this, the daycare accounts for roughly 1% of total site activity. Accordingly, its estimated share of the 500-space Parkpalette is approximately five parking spaces, reflecting proportional daily usage. Additionally, the Troplo Kita campus features a designated parking area with 25 spaces intended exclusively for visitors and guests of the daycare center, as shown in Figure 5.8.



Figure 5.8 Parking Spaces for Guests of Troplo Kids Daycare Center (Author)

Based on the analysis, the Troplo Kita project does not comply with the LEED v4 Reduced Parking Footprint credit requirements. The estimated number of parking spaces required by the project is 30, which is well above the LEED requirement of a maximum of 19 spaces, as shown in Table 5.7.

Table 5.7 Points earned by Troplo Kids daycare center in Reduced Parking Footprint (Author)

Criteria ID	Points	Item	Value	Points Earned
Reduced Parking Footprint - LTc6	1	Base requirement (0.3 × 100 children)	30 spaces	0
		Reduction (40% for Case 2)	-12 spaces	
		Allowed max (LEED)	18 spaces	
		Troplo Kita's estimated share of Parkpalette	5 spaces	
		5% Carpool	1 Spaces	
		Parking for Troplo Kita Guests	25 spaces	
		Total Parking By Troplo Kita	30 Spaces	

5.2.5 Green Vehicles (LTc7)

5.2.5.1 Intent of Credit

To minimize environmental pollution by encouraging the use of alternative transportation technologies and reducing reliance on conventionally fueled vehicles (USGBC, Green vehicles, 2014).

5.2.5.2 LEED Criteria

LEED credit criteria and thresholds were referenced directly from the U.S. Green Building Council's official website, USGBC (2014), and these are as follows;

Green Passenger Vehicles – Evaluation Criteria

This credit aims to promote the use of low-emission and fuel-efficient vehicles by requiring two key measures: the provision of preferred parking for green vehicles and the installation of electric vehicle (EV) charging infrastructure.

Preferred Parking for Green Vehicles

Projects must reserve 5% of total parking spaces as preferred parking for qualifying green vehicles. These spaces should be:

1. Located in more convenient areas (e.g., near building entrances)
2. Marked through signage or pavement markings
3. Enforced to ensure only eligible vehicles use them

Vehicles that qualify must receive at least a 45 green score, according to the ACEEE (American Council for an Energy-Efficient Economy) rating system, or meet an equivalent national standard (e.g., European low-emission criteria) in cases where the project includes multiple parking areas (such as for staff and visitors), the 5% requirement must be applied proportionally across all sections.

As an alternative compliance option (especially relevant for European projects), a 20% discount on parking fees may be offered instead of reserved spaces. This discount must be:

1. Permanently available
2. Publicly posted and visible at the entrance or payment point
3. Accessible to all qualifying green vehicle users

2. Electric Vehicle Charging Infrastructure

In addition to preferred parking, the project must also provide EV charging facilities. Under Path 1, at least 2% of total parking spaces must be equipped with Electric Vehicle Supply Equipment (EVSE). These charging spaces must:

- Be separate from the preferred parking spaces
- Be reserved exclusively for plug-in electric vehicles
- Provide Level 2 or higher charging (208–240 volts)
- Use internationally recognized connectors, such as:
 - IEC 62196 (Type 2 plug) in Europe
 - SAE J1772 in North America

Be network-capable, allowing remote monitoring, control, and participation in demand-response or time-of-use electricity pricing programs.

5.2.5.3 Measured Performance

This section evaluates the project's alignment with LEED v4.1 BD+C credit requirements for Green Passenger Vehicles, which includes provisions for parking availability, electric vehicle (EV) charging infrastructure, and preferred parking for low-emission vehicles.

1. Parking Availability

Troplo Kids is situated on the Beiersdorf Campus, which includes the Parkpalette at Beiersdorfstraße 9. The Parkpalette offers approximately 500 parking spaces for Beiersdorf employees, including parents and staff of Troplo Kids. Additionally, the Troplo Kita campus features a designated parking area with 25 spaces intended exclusively for visitors and guests of the daycare center, as shown in Figure 5.9. According to LEED guidelines, parking owned or leased by the project or shared but used by project occupants qualifies for the credit calculation. This parking facility meets LEED's definition of project-served parking.



Figure 5.9 Designated Parking for the Guest of Troplo Kids daycare center (Author)

2. EV Charging Infrastructure:

The Parkpalette includes 2 x 22 kW AC EV chargers (Type 2 / IEC 62196), marked with RWE branding (GoingElectric, 2015). Chargers are network-capable and accessible via a Beiersdorf employee card, indicating that they are intended for internal use only. LEED requires EVSE in 2% of total parking spaces, meaning 10 chargers are needed out of 500 spaces. Only two chargers are confirmed, which is below the 2% minimum required by LEED. Further verification is needed to confirm if additional chargers are present elsewhere in the facility.

The designated parking area, comprising 25 spaces, is reserved exclusively for visitors and guests of the daycare center. However, the facility does not include any electric vehicle (EV) charging stations or signage indicating preferential parking or discounted rates for low-emission or fuel-efficient vehicles.

3. Preferred Parking for Green Vehicles:

No documentation or visual signage confirms the existence of dedicated green vehicle spaces (e.g., priority for hybrids or electric cars).

1. No evidence was found (visual or documented) of:
2. Preferred parking signage for low-emission or hybrid vehicles
3. Designated green vehicle spaces
4. Parking fee discounts for green vehicles

LEED requires:

1. 5% of parking spaces are designated as preferred for green vehicles
2. OR a 20% discount on parking rates for green vehicles, clearly posted and permanently available

The LEED credit evaluation for Green Vehicles (LTc7) shows that while parking is available and used by Troplo Kids staff and parents, the project currently does not meet the requirements for preferred parking for green vehicles, and the EV charging infrastructure is only partially compliant, with just 2 confirmed chargers out of the 10 required (2% of 500 spaces) and zero for parking reserved for Troplo Kids guest. As a result, 0.5 out of 1 possible point can be considered achievable, pending further verification of EV charging capacity in Parkpalette, as shown in Table 5.8.

Table 5.8 Points earned by Troplo Kids daycare center in Green Vehicles (Author)

Criteria ID	Points		Criteria	Requirement	Status	Notes	Points Earned
Green Vehicles LTc7	1	0.5	1. Project Parking Availability	Parking must serve project occupants	yes	Parkpalette and Troplo Kita Parking used by daycare staff and parents	0
			2. Preferred Parking for Green Vehicles	5% of spaces OR 20% fee discount	No	No signage, markings, or discount policy visible	
		0.5	3. EV Charging Infrastructure (2%)	At least 2% of total spaces with EV chargers	Partial (not confirmed)	Only 2 confirmed out of 500, needs 10 chargers total	0.5

5.3 Sustainable Sites (SSc1-SSc5)

5.3.1 Site Assessment (SSc1)

5.3.1.1 Intent of Credit

The credit aims to analyze existing site conditions prior to the design phase in order to explore sustainable development possibilities and guide informed decision-making in the planning and layout of the site (USGBC, Site assessment, 2014).

5.3.1.2 LEED Criteria

According to USGBC (2014), a comprehensive site survey or assessment must be conducted and documented prior to the design process. This evaluation should include the following components:

1. **Topography:** Mapping of contours, identification of distinct landform features, and analysis of any slope instability or erosion risks.

2. **Hydrology:** Identification of flood-prone zones, delineated wetlands, water bodies such as lakes and streams, shoreline conditions, opportunities for harvesting and reusing rainwater, and the initial water storage capacity of the site, as defined by TR-55 or its regional equivalent.
3. **Climate:** Analysis of solar access, potential for heat island formation, orientation to seasonal sun paths, predominant wind directions, and typical monthly patterns of precipitation and temperature.
4. **Vegetation:** Documentation of existing plant communities, classification of greenfield areas, mapping of mature or significant trees, identification of rare or protected species and habitats, and detection of invasive plant species.
5. **Soils:** Classification using the NRCS soil survey, identification of prime farmland (as defined by the USDA), assessment of soil health, and differentiation between previously undisturbed and disturbed soils. Equivalent regional standards may be applied for projects located outside the United States.
6. **Human Use:** Assessment of visual quality, accessibility to nearby transportation infrastructure, compatibility with surrounding land uses, and the potential for reusing or recycling materials found on-site.
7. **Public Health Considerations:** Proximity to sensitive or at-risk populations, availability of nearby recreational or physical activity facilities, and closeness to major sources of air pollution.

The site assessment must illustrate the interrelationships among these elements and explain how they influenced the project's overall design. Any areas not addressed must be justified within the assessment report.

5.3.1.3 Measured Performance

Hamburg experiences an average annual precipitation of approximately 800 to 900 mm, with the highest rainfall occurring in July and August and the lowest levels recorded in February and March. Precipitation is generally well-distributed throughout the year, with no pronounced dry season. The prevailing wind direction is from the west and southwest, influenced by maritime weather systems from the North Sea, resulting in moderate wind speeds that are typically stronger during the winter months and milder in the summer. Solar exposure is most pronounced between May and August, with an average daily sunshine of 6 to 8 hours. In contrast, the least amount of sunshine occurs during December and January, with daily averages

of approximately one to two hours of sunshine. Annually, Hamburg receives between 1,500 and 1,700 hours of sunshine (metablue, 2025).

According to HamburgGeoportal (2025), the project site is situated at an elevation of approximately 15 meters above sea level, which is significantly higher than the city's minimum elevation of -3 meters, as shown in Figure 5.10. This elevation minimizes the risk of flooding and facilitates adequate natural drainage. The site does not fall within any designated flood-prone zones and exhibits no apparent issues related to slope instability or erosion. Furthermore, the location benefits from strong connectivity to the public transportation network, enhancing its accessibility and integration with the surrounding urban infrastructure, as discussed above.



Figure 5.10 Elevation of Troplo Kids Daycare Center (HamburgGeoportal, 2025)

Using publicly accessible resources such as Geoportal Hamburg and climate database each of the required components topography, hydrology, climate, vegetation, human use, and public health context was systematically analyzed. While the assessment did not inform the original design process, the findings provide insight into how well the existing conditions support LEED-aligned sustainable development. Based on this reconstruction, the credit is considered potentially achievable, provided that the required documentation is compiled and submitted in accordance with LEED guidelines.

5.3.2 Site Development - Protect or Restore Habitat (SSc2)

5.3.2.1 Intent of Credit

The objective is to preserve existing natural environments and rehabilitate previously disturbed areas in order to enhance ecological value, support native biodiversity, and promote the development of resilient habitats (USGBC, Site development - protect or restore habitat, 2014).

5.3.2.2 LEED Criteria

LEED credit criteria and thresholds were referenced directly from the USGBC (2014), and it aims to enhance ecological performance by conserving natural site features and restoring degraded areas to support biodiversity. The requirements are structured around two key components:

LEED credit criteria and thresholds were referenced directly from the USGBC (2014), and it aims to enhance ecological performance by conserving natural site features and restoring degraded areas to support biodiversity. The requirements are structured around two key components:

Preservation of Greenfield Areas

If greenfield land (undeveloped or undisturbed areas) is present on the project site, at least 40% of that area must be preserved and protected from any development or construction-related disturbance. This ensures the conservation of natural habitats and the preservation of existing ecological functions.

On-Site Restoration

To earn points under this option, the project must restore at least 30% of all previously disturbed site areas, including the building footprint, using native or adapted vegetation. This approach supports local biodiversity and ecological resilience. In cases where the project achieves a Floor Area Ratio (FAR) of 1.5 or greater, vegetated roofs may be included in this calculation, provided they are planted with native or adapted species that contribute to habitat creation.

Additionally, any disturbed or compacted soils within the development footprint that are to be revegetated must be restored to support vegetation functionally. Restoration must meet specific soil quality benchmarks:

1. Reused soils (both on-site and imported) must be suitable for their intended ecological functions.
2. Imported topsoil must not come from sensitive agricultural lands (e.g., prime farmland or greenfield sites) unless it is a byproduct of another construction process.

Restored soils should demonstrate compliance with reference criteria in at least four of the following five categories:

1. Organic matter content

2. Degree of compaction
3. Water infiltration capacity
4. Soil biological activity
5. Chemical characteristics

Vegetated areas designed explicitly for stormwater management may be exempt from the soil restoration criteria, provided they are addressed in alignment with LEED's Rainwater Management credit. Similarly, dedicated athletic fields intended solely for sports use are excluded from the restoration requirements and cannot be counted toward the minimum restoration area.

5.3.2.3 Measured Performance

To assess compliance with the LEED credit, comprehensive key milestones used for this evaluation include imagery from the years 2008 (pre-construction), 2013 (during construction), and 2015 (post-construction), as shown in Figure 5.11. The total site area of the Troplo Kids Campus in Hamburg was approximately 3,400 m².

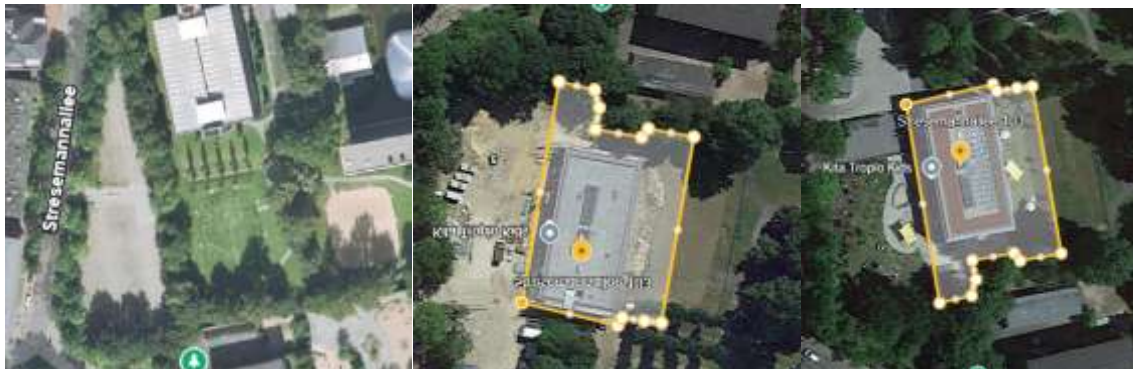


Figure 5.11 Preconstruction (2008), During Construction (2013) and Post Construction (2015) left to right, respectively of Troplo Kids Daycare Center (HamburgGeoportal, 2025)

Preservation of Greenfield Areas

Greenfield areas were defined as previously undisturbed zones typically characterized by natural vegetation, including grasslands and tree cover, prior to any construction activity. Historical imagery from 2008 indicates that approximately 1,904 m² of the site qualified as greenfield. According to LEED guidelines, a minimum of 40% of such areas (i.e., 761.6 m²) must be preserved to meet the credit requirement.

Post-construction assessments in 2014 show that only 259 m² of the original greenfield area remained protected and undisturbed, as shown in the figure. This figure constitutes

approximately 13.6% of the original greenfield area, falling significantly short of the required 40% preservation threshold. Consequently, the project does not meet the LEED criteria for greenfield preservation.

On-Site Restoration of Disturbed Areas

Despite the shortfall in greenfield preservation, the project demonstrates significant performance in the on-site restoration of previously disturbed areas. During the construction phase, the disturbed site area, including the building footprint, staging zones, and temporary access, was calculated to be approximately 3,167 m².

By 2014, 1,171 m² of this area had been restored through the introduction of vegetated surfaces, including lawns, tree planting zones, and informal garden areas. This restoration accounts for approximately 37% of the disturbed land, exceeding the LEED requirement of a minimum 30% restoration using native or adapted vegetation.

Field observations and comparisons with regional botanical references suggest the reestablishment of native species, such as European Hornbeam (*Carpinus betulus*) and Pedunculate Oak (*Quercus robur*), within the restored zones. Both species are indigenous to the Hamburg region and make a significant contribution to habitat value, urban biodiversity, and ecological resilience.

Although no direct soil quality sampling was available, the successful growth of diverse vegetation, combined with a visual assessment, suggests that post-construction soil amendments may have supported restoration objectives. Although not all five LEED soil quality criteria could be formally verified, it is plausible that the site meets several benchmarks, including sufficient organic matter, reduced compaction, and adequate infiltration capacity.

It is essential to note that restored areas included functional green spaces, such as playground lawns and tree-covered patches, but excluded surfaces like paved walkways and dedicated athletic zones, by LEED credit guidelines.

The project is eligible for a total of two points under the LEED v4 Site Development Protect or Restore Habitat credit. However, only one point was awarded due to partial fulfillment of the credit requirements, as shown in Table 5.9.

Table 5.9 Points earned by Troplo Kids daycare center in Protect and Restore Habitat (Author)

Credit ID	Points	Category	Requirement	Value Earned	Notes	Points Earned	
Site Development - Protect or Restore Habitat SSc2	2	1	Greenfield Area (Pre-construction)	Identify total undisturbed (natural) area	1,904 m ²	—	0
			Required Greenfield Preservation	≥ 40% of pre-construction greenfield area	761.6 m ²	—	
			Actual Preserved Greenfield Area	≥ 761.6 m ²	259 m ²	Not Compliant	
			% of Greenfield Preserved	≥ 40%	13.60%		
	1	1	Disturbed Area (During Construction)	Total area affected by construction activities	3,167 m ²	—	1
			Required Restoration Area	≥ 30% of disturbed area using native/adapted vegetation	950.1 m ²	—	
			Actual Restored Area	≥ 950.1 m ²	1,171 m ²	Compliant	
			% of Area Restored	≥ 30%	37%		
			Vegetation Used in Restoration	Native or adapted species	<i>Carpinus betulus</i> , <i>Quercus robur</i>	Compliant	
			Soil Quality Benchmarks Verified	≥ 4 out of 5 (if assessed)	Visual evidence only, not formally tested	Partially Verified (Visual)	

While the project successfully met the on-site restoration criteria, restoring approximately 37% of previously disturbed areas using native and adapted vegetation, it did not meet the minimum threshold of preserving 40% of the pre-construction greenfield area, achieving only 13.6% preservation. As a result, the credit was partially achieved, with one point awarded for on-site restoration and no points granted for greenfield preservation.

5.3.3 Open Spaces (SSc3)

5.3.3.1 Intent of Credit

The aim of this credit is to design exterior open spaces that promote environmental engagement, foster social interaction, support passive recreation, and encourage physical activity (USBGC, Open space, 2014).

5.3.3.2 LEED Criteria

According to USBGC (2014), criteria under the Sustainable Sites category, the project is eligible for the Open Space credit if at least 30% of the total site area, including the building footprint, is dedicated to outdoor open space. Of this outdoor area, a minimum of 25% must be vegetated with diverse plantings or overhead vegetated canopies; standard turf grass does not qualify. The outdoor space must be physically accessible and designed to support social, recreational, or ecological functions, such as pedestrian plazas, recreational areas, gardens, or habitat zones that allow human interaction.

For high-density projects with a Floor Area Ratio (FAR) of 1.5 or higher, LEED permits the inclusion of accessible vegetated roofs and usable roof terraces to meet the open space requirements. Additionally, wetlands or naturally landscaped ponds may be counted, provided their slopes are shallow (a gradient of 1:4 or less) and adequately vegetated.

5.3.3.3 Measured Performance

To evaluate compliance with the LEED BD+C v4 Open Space Credit, a detailed analysis of the site was performed using the architectural site plan and the Geoportal Hamburg area measurement tool, as shown in Figure 5.12.



Figure 5.12 Total Project Site (Green) and Building Footprint (Orange) of Troplo Kids Daycare Center (HamburgGeoportal, 2025)

The results are summarized below:

Total site area: 3,400 m²

Building footprint: 800 m²

Total outdoor open space: 2,600 m²

The outdoor space must be equal to or more than 30% of the total site:

Outdoor space area \geq 30% \times (Total Site Area)

$$\frac{\text{Total Outdoor Open Space}}{\text{Total Site Area}} = \frac{2,600 \text{ m}^2}{3,400 \text{ m}^2} \times 100 = 76.5\%$$

This exceeds the LEED requirement that a minimum of 30% of the total site area must be dedicated to open space.

Vegetated Area Requirement

Additionally, according to LEED, at least 25% of the open area must be planted with plants other than turf grass. Based on analysis of the site plan and local vegetation data, approximately 780 m² of the open space is covered by trees and diverse plantings.

Percentage of vegetated open space:

$$\frac{\text{Vegetation Space}}{\text{Total outdoor Open Space}} = \frac{890 \text{ m}^2}{2,600 \text{ m}^2} \times 100 = 34\%$$

This meets the LEED threshold of 25% vegetated cover within the outdoor open space.

Outdoor Space Functionality

The outdoor space is fully accessible and designed to promote a variety of social, recreational, and sensory experiences for children and staff. Key elements that support this include Pedestrian-oriented spaces featuring benches, walkways, and seating areas for social interaction.

According to the report of Kadawittfeldarchitektur (2015) and field observation following Recreational play features are provided;

- Hopscotch and Big Bobby Car Track
- Playground equipment in Grassed zones
- A sandpit with wooden seating steps.
- A water play table and a willow tunnel.
- Mulch-covered areas with climbing frames, a net swing, and rocking animals.

Educational and sensory spaces, such as:

- A herb garden and playhouse for interactive learning.
- A grassed mound with a built-in slide.

A sculptural installation, the “tin can telephone,”—designed by artist Fabian Wendling, integrates artistic and play functions, including climbing, balancing, drumming, and imaginative use.

LEED allows vegetated roofs to count toward open space credits only when the Floor Area Ratio (FAR) is greater than or equal to 1.5. The FAR is calculated using the following formula:

$$FAR = \frac{1750 \text{ m}^2}{3,400 \text{ m}^2} = 0.51$$

The Floor Area Ratio (FAR) for the building is less than 1.5, based on the total floor area of the site area. According to LEED guidelines, this excludes the use of vegetated roof areas in calculating the 25% vegetated open space requirement.

The project meets all LEED v4 BD+C Open Space credit requirements. Over 76% of the site is open space, with more than 30% of it vegetated (excluding turf grass). The outdoor areas are accessible and support a wide range of recreational and social activities. Although the FAR is below 1.5, excluding vegetated roofs from the calculation, the credit is fully achieved, as shown in Table 5.10.

Table 5.10 Points earned by Troplo Kids daycare center in Open Spaces (Author)

Criteria ID	Points	Criteria	Requirement	Value Earned	Points Earned
Open Spaces SSc3	1	Minimum Open Space	≥30% of total site area	76.50%	1
		Minimum Vegetated Portion of Open Space	≥25% of open space must be vegetated (excluding turf grass)	34%	
		Physically Accessibility	Open space must be physically accessible to building occupants	Accessible play areas, walkways, and gardens	
		Types of Open Space	Must include at least one of the following: Pedestrian-oriented Recreation-oriented Garden with diverse vegetation Community garden or food production Preserved or created habitat with interaction	Multiple types present: Pedestrian-oriented areas Recreational play zones Garden with herb plants and vegetation Artistic and interactive features	

5.3.4 Heat island reduction (SSc5)

5.3.4.1 Intent of Credit

The aim of the credit is to mitigate the impact on local microclimates and reduce adverse effects on both human comfort and natural habitats by limiting the formation of heat islands (USGBC, Heat island reduction, 2014)

5.3.4.2 LEED Criteria

According to USGBC (2014), to address the thermal impacts of built environments, this credit offers two compliance paths focused on mitigating the formation of heat islands, which can negatively affect human comfort, microclimates, and ecosystems.

Option 1: Nonroof and Roof Strategies (2 Points; 1 Point for Healthcare Projects)

The project should the following criteria as shown in Figure 5.13,

$$\frac{\text{Area of Nonroof Measures}}{0.5} + \frac{\text{Area of High-Reflectance Roof}}{0.75} + \frac{\text{Area of Vegetated Roof}}{0.75} \geq \frac{\text{Total Site Paving Area}}{\text{Total Roof Area}}$$

Figure 5.13 Roof and Non-Roof Criteria for calculation of Heat Reduction Island Criteria (USGBC, Heat island reduction, 2014)

Alternatively, compliance can also be demonstrated by calculating a weighted average of Solar Reflectance Index (SRI) and Solar Reflectance (SR) values using a combination of applicable strategies.

Non-Roof Measures

- **Vegetative Shading:** Utilize existing vegetation or introduce plantings that will provide shade to hardscape surfaces such as walkways, playgrounds, and pavements. The selected plantings must be capable of achieving substantial canopy coverage within 10 years of installation and must be in place by the time the project is occupied. Artificial turf does not qualify.
- **Energy-Producing Shade Structures:** Install overhead structures equipped with renewable energy technologies, such as solar panels or wind turbines, that also function as shade providers.
- **Architectural Shading Elements:** Incorporate shading devices or canopies made of materials with a Solar Reflectance (SR) value of at least 0.28 after three years of exposure to weather. If aged SR data is unavailable, an initial SR of at least 0.33 at installation is acceptable.
- **Vegetated Shade Structures:** Use living vegetation integrated into structural systems to provide shading.

- Reflective Paving Materials: Employ paving systems with an aged SR of at least 0.28 (or an initial SR of 0.33 if aged data is not available).
- Open-Grid Pavement: Apply permeable paving systems where a minimum of 50% of the surface area is unbound, allowing vegetation or soil exposure.

High-Reflectance Roofing:

Roof materials must meet or exceed the Solar Reflectance Index (SRI) values listed in LEED's standard, as shown in Figure 5.14, based on the roof's slope. These values should reflect the three-year aged condition; however, if unavailable, initial SRI values may be used as an alternative.

	Slope	Initial SRI	OR	3-year aged SRI
Low-sloped roof	≤ 2:12	82		64
Steep-sloped roof	> 2:12	39		32

Figure 5.14 Value of Minimum Solar Reflectance Index for Roof Slope (USGBC, Heat island reduction, 2014)

Vegetated Roof:

Install green roofing systems that incorporate soil and vegetation to mitigate heat gain naturally.

Option 2: Covered Parking (1 Point)

This approach requires that at least 75% of all parking spaces be situated beneath a cover that meets one of the following criteria:

1. A roofing system with an aged SRI of at least 32 (or an initial SRI of at least 39, if aged data is unavailable),
2. A vegetated roofing system,
3. A cover integrated with renewable energy systems such as solar panels or wind turbines.

5.3.4.3 Measured Performance

To evaluate the project's compliance with LEED's Heat Island Reduction credit, a combined strategy of non-roof measures, high-reflectance roofing, and vegetated roofing was assessed on the Troplo Kids Hamburg campus.

Nonroof Measures:

As part of the non-roof strategy, the Troplo Kids Hamburg campus incorporates several interventions aimed at mitigating the heat island effect on paved surfaces, such as walkways and parking areas. Out of the total 1,481 m² of paved area, approximately 633 m² are covered by nonroof measures, including:

1. Tree plantations that provide natural shading to walkways and play zones.
2. Photovoltaic (solar panel) installations are used to shade paved surfaces, consistent with LEED's provision for shading by energy-generating systems.

These measures directly contribute to reducing surface temperatures and improving microclimatic conditions in outdoor spaces frequently used by children and staff. However, the remaining 923 m² of paved area does not feature compliant shading or reflective materials and, therefore, is not counted toward LEED compliance.

Vegetated Roof

The project also includes the installation of a vegetated roof, covering approximately 367 m² of the total 800 m² roof area, as shown in Figure 5.15.



Figure 5.15 Green Roof and Solar Panels (Google Earth)

High-reflectance roof

Due to the unavailability of construction documentation, the roofing materials used in the project were assessed based solely on photographic interpretation. This method, while helpful in visually identifying general surface types such as vegetated areas, solar panels, and gravel or membrane roofing, does not provide sufficient detail to accurately determine the thermal and optical properties required to calculate Solar Reflectance Index (SRI) values. As a result, reliable SRI calculations could not be performed. An estimated roof area of approximately 185 m² was visually identified as potentially having a high-reflectance surface; however, without verified SRI data meeting LEED thresholds (SRI \geq 82 for low-sloped roofs), this area cannot be formally credited under the high-reflectance roof strategy as shown in Table 5.11. Even

under optimistic assumptions, when applying the weighted compliance formula, the total compliant roof area falls below the minimum requirement set by LEED. Therefore, this limitation directly affects the project's ability to earn points under the Heat Island Reduction credit, highlighting the importance of documented material specifications when pursuing certification post-construction.

Table 5.11 Roof, Nonroof and High Reflective Roof values for Troplo Kids Daycare Center (Author)

Element	Area (m ²)
Total Paved Area (nonroof)	1,481
Total Roof Area	800
Vegetated Roof Area	367
Nonroof Measures (shaded)	633
High-Reflectance Roof	185

As per LEED v4 guidelines, the following above values in the table are used in the given formula:

$$\frac{633 \text{ m}^2}{0.5} + \frac{185 \text{ m}^2}{0.75} + \frac{367 \text{ m}^2}{0.75} \geq 1,481 \text{ m}^2 + 800 \text{ m}^2$$

$$2,002 \neq 2,281$$

Although the vegetated roof and nonroof shading strategies were effective and met LEED criteria, the overall credit could not be achieved.

The Troplo Kids Hamburg project did not achieve the LEED Heat Island Reduction credit. Although it included a 367 m² vegetated roof and 633 m² of nonroof shading strategies, the roofing materials lacked verified SRI values and did not meet LEED requirements, resulting in non-compliance and zero points out of two.

5.4 Energy Performance

Owing to limited access to primary site data, particularly façade measurements and detailed spatial geometry, this study did not perform independent energy simulations. Instead, the analysis relies on verified secondary sources, including technical information provided by the

architectural report. While the lack of direct energy modeling constitutes a limitation, the available data is comprehensive enough to support a meaningful assessment.

5.4.1 Material Characterization

The energy performance of the DGNB Platinum-certified building is shaped by stringent sustainability requirements integrated early in the planning process. Thermal building simulations ensured optimal coordination between the building's volume and technical systems to meet thermal comfort demands in both summer and winter seasons. The building envelope is optimized for airtightness and insulation, with average U-values of **0.16 W/m²K** for opaque components and **1.14 W/m²K** for transparent components, which include triple glazing (kadawittfeldarchitektur, 2015). These values reflect a high standard of thermal performance, reducing energy losses through walls, roofs, and windows.

The building features a high-performance insulated façade system designed to optimize both energy efficiency and long-term durability. According to the kadawittfeldarchitektur (2015) report, the envelope consists of a powder-coated, rear-ventilated aluminum panel system mounted on a galvanized steel sub-construction. This rear-ventilated cladding not only provides weather protection and aesthetic uniformity but also enhances the thermal performance of the façade by creating an air buffer that mitigates heat transfer and helps control moisture. Such systems are known to contribute significantly to passive energy savings by reducing reliance on mechanical heating and cooling.

The daycare center is constructed using a solid reinforced concrete structure, which includes load-bearing walls, vertical supports (columns), a ground slab, and horizontal floor slabs. The internal configuration features non-load-bearing masonry and gypsum board partition walls, enabling flexibility in space utilization. The interior fit-out also includes acoustic suspended ceilings made of gypsum board and slip-resistant floor coverings that enhance safety and accessibility. The use of reinforced concrete for the primary structure introduces thermal mass into the building, which helps regulate indoor temperatures by absorbing and gradually releasing heat. Internally, non-load-bearing gypsum board partitions and acoustic suspended ceilings support sound absorption and interior comfort (kadawittfeldarchitektur, 2015).

The flat roof is extensively greened, contributing to stormwater retention, biodiversity, and mitigation of the urban heat island effect (kadawittfeldarchitektur, 2015).

5.4.2 Facade Design and Windows

The façade design incorporates large glazed surfaces complemented by exterior shading devices, which aid in controlling solar heat gains while maximizing daylight, as shown in the Figure.

A study could not perform energy simulation, and the exact window-to-wall ratio is unknown. However, visual inspection and the architect's report show that the east and west façades of the building contain glazed windows over the façade, approximately leading to a 100% window-to-wall ratio on the east and west sides, as seen in Figure 5.16.



Figure 5.16 Large Glazed Window on East Facade of Troplo Daycare Center (kadawittfeldarchitektur, 2015)

The building's east and west façades are characterized by large glazed areas framed with deep, extruded rectangular and square modules, which serve both aesthetic and functional purposes while reducing heat gain during summer, as shown in Figure 5.17. In terms of fenestration, the building features insulated aluminum-framed windows and doors equipped with triple glazing, providing both thermal and acoustic insulation. These elements help to minimize unwanted heat loss in winter and limit solar heat gain in summer, ensuring a stable and comfortable indoor environment throughout the year. The integration of exterior shading devices designed in the same color tone as the main façade further supports this passive design strategy. These devices reduce glare and overheating while maintaining a high level of daylight penetration, thereby contributing to visual comfort and reducing the need for artificial lighting.



Figure 5.17 Deep Extruded Façade (kadawittfeldarchitektur, 2015)

According to Suncalc (2025), sun path analysis at the Hamburg site, the building experiences substantial solar exposure on these façades during the early morning (east) and late afternoon (west), especially in summer when the sun rises at 04:49 and sets at 21:54, with low-angle radiation penetrating directly into the interior spaces as shown in Figure 5.18. In winter, the sun's trajectory remains low in the sky, with limited east-west exposure, but the glazed surfaces still admit valuable passive solar gains.



Figure 5.18 Solar Exposure during Summer (Suncalc, 2025)

The extruded geometry acts as a passive shading strategy, reducing the intensity of direct sunlight and mitigating glare and overheating, particularly during the critical summer hours. These deep frames function similarly to horizontal and vertical fins, casting shadows on the glazing and improving visual comfort, as shown in Figure 5.19.



Figure 5.19 Passive Shading by Extruded Façade in Interior Spaces (kadawittfeldarchitektur, 2015)

Given that the school operates from 6:45 AM to 6:00 PM, the building is occupied during the critical hours of east and west solar exposure, especially in summer. This further validates the importance of the façade design, as deep extruded frames and exterior shading devices help mitigate direct solar gains during these hours. Their orientation and function are thus not only climatically appropriate but also tailored to the building's operational schedule, ensuring thermal comfort and daylight control precisely when spaces are in active use, as shown in Figure 5.20. This alignment between building usage and passive design strategies contributes significantly to the building's energy efficiency and indoor environmental quality.



Figure 5.20 Interior Design and color coordination (kadawittfeldarchitektur, 2015)

5.4.3 Energy Consumption

A variety of practical and integrated building systems support the nursery facility. A combined heat and power (CHP) plant located on the Beiersdorf AG property supports the district heating network, which provides the heat supply. Additionally, as shown in Figure 5.21, the roof features a photovoltaic array comprising flat-plate solar collectors that help generate renewable

energy on-site. A water-based underfloor heating system provides consistent thermal comfort throughout the interior.

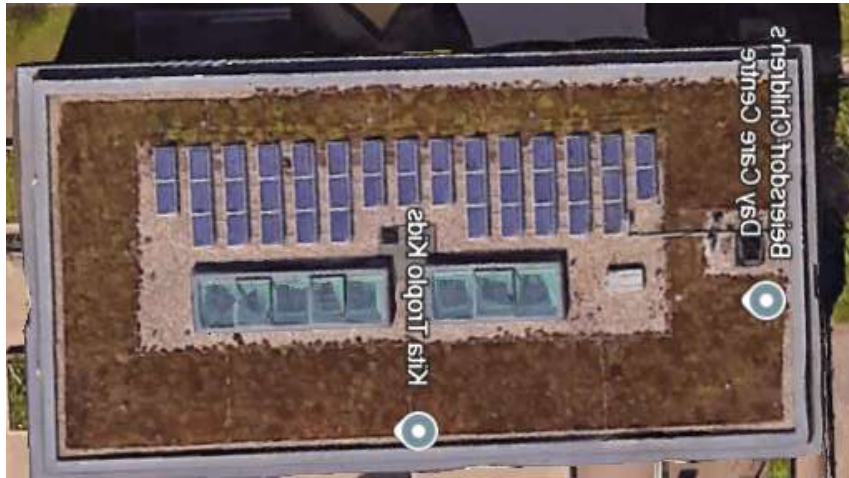


Figure 5.21 Green Roof and Solar Panels (Google Earth)

Natural light and movable ventilation are available in all main areas, including group rooms, and are complemented by a heat-recovery mechanical ventilation system. To order to maintain energy efficiency and air quality throughout, interior spaces without external windows are also equipped with specialized mechanical ventilation systems (kadawittfeldarchitektur, 2015).

Efficient building services, such as ventilation systems with high heat recovery rates, an underfloor heating system, and connection to a district heat network, further enhance the building's energy efficiency. Renewable energy production is integrated through a roof-mounted photovoltaic array with an annual output of 19,600 kWh (kadawittfeldarchitektur, 2015).

Additional sustainability measures include blower-door tests confirming airtightness (air exchange rate $n_{50} = 0.64$ 1/h), use of low-emission materials to ensure good indoor air quality, and resource efficiency strategies such as water-saving fittings and a planted green roof to reduce rainwater runoff (kadawittfeldarchitektur, 2015)..

Energy consumption data indicate that the actual final energy use is 84.7 kWh/m²a, significantly lower than the EnEV 2009 required value of 202.6 kWh/m²a, thus undercutting the regulation by 58.2%. The building's final energy consumption is approximately 30% lower than the requirements set by EnEV 2009, while its primary energy use is reduced by around 60%. This substantial reduction demonstrates the building's exceptional energy performance, exceeding standard requirements and justifying its DGNB Platinum certification.

CHAPTER 6 RESULT AND DISCUSSION

This chapter discusses the findings obtained through the assessment of a DGNB Platinum-certified building against selected LEED criteria, namely Location and Transportation, Sustainable Sites, and Energy Performance. The results were analyzed to determine the extent to which the building complies with LEED standards, identify strengths and weaknesses, and explore the alignment or divergence between the two certification systems. The discussion is organized thematically and explicitly mapped to the study's Research Questions.

6.1 Location and Transportation

6.1.1 Proximity to Public Transportation System

The project achieved a maximum of 4 points for LEED v4 LTc4: Access to Quality Transit, as shown in Figure 6.1. It lies 750 m from the nearest U-Bahn station and 250 m from a central bus terminal. The selected transit line provides 381 departures per week in a single direction, exceeding the LEED threshold of 360 weekly departures. This performance indicates excellent accessibility, likely reducing reliance on private vehicles. Proximity to frequent bus and regional rail services also contributes to lower greenhouse gas emissions, reduced air pollution and noise levels, and overall alignment with LEED's sustainability objectives.

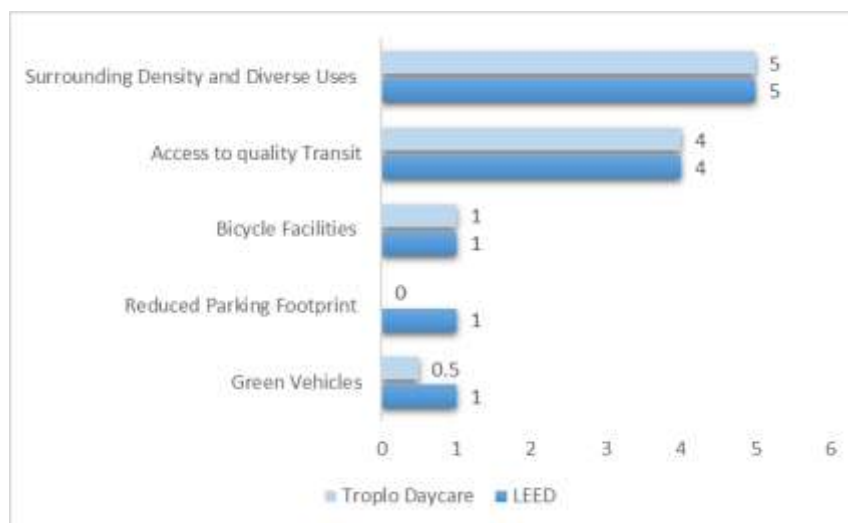


Figure 6.1 Score achieved by each credit under Location and Transportation under LEED v4 BD+C School (Author)

6.1.2 Walkability and Access to Amenities

The project received the maximum 5 points for the Surrounding Density and Diverse Uses credit, as shown in Figure 6.1. It secures three points for Surrounding Density with a high combined density of 59,286 m²/ha, indicating a highly urbanized setting. Moreover, 2 points are due to its location in a highly developed urban area with a wide range of amenities, such as educational institutions, parks, grocery stores, pharmacies, and public services, all within a 400-meter walking radius. This demonstrates excellent alignment with LEED's goals of encouraging walkable, mixed-use neighborhoods and reducing car dependency. This high concentration of essential amenities within walkable distance significantly enhances the project's walkability and connectivity, aligning with LEED's goal of promoting mixed-use, pedestrian-friendly neighborhoods and reducing reliance on private vehicles.

A direct weightage comparison of the DGNB criteria sets under which the building was certified is difficult, as only the latest DGNB System New Construction Criteria Sets (2023) is currently assessable on the website. Therefore, the percentage weightage of the DGNB criteria sets of 2023 is used to compare the difference in weightage and criteria between USGBC, LEED Credit Library New Construction (2014). The most closely related criteria are taken from DGNB criteria sets of 2023 to match the selected LEED v4 criteria. It will demonstrate how the latest DGNB criteria sets give weight to specific criteria and their measurements.

For instance, LEED v4 BD+C School places greater emphasis on Location and Transportation (LT), with credits such as Access to Quality Transit (3.6%) and Surrounding Density and Diverse Uses (4.5%) carrying substantial weight. In contrast, the DGNB assigns a relatively low weight of 1.3% each to the Site Quality Criteria categories of Transport Access and Access to Amenities, as shown in Table 6.1.

Table 6.1 LEED and DGNB criteria weightage in subcategory

% weightage	DGNB Credits	DGNB (category)	LEED Credits	LEED (category)	% weightage
1.3	Access to amenities	Site Quality	Surrounding Density and Diverse Uses	Location and Transportation	4.5
1.3	Transport Access		Access to quality Transit		3.6

Despite this difference in scoring emphasis, the building in question performed well under LEED, mainly due to its location in a dense urban environment with proximity to essential services, frequent public transportation, and access to a wide range of amenities, including schools, parks, grocery stores, and pharmacies. The building's high performance in a criterion that is more heavily weighted in LEED but less so in DGNB suggests that inherent site

advantages, such as excellent transport connectivity and diverse land use within walking distance, can positively impact certification outcomes even when scoring emphasis varies. This demonstrates the building’s resilience across various rating systems and emphasizes the value of comprehensive sustainability planning, which extends beyond weighted priorities alone. This outcome illustrates DGNB’s holistic and context-sensitive assessment approach, where strong performance across multiple sustainability domains, including accessibility to diverse urban functions, can result in a high certification level, even if specific criteria carry lower weightings. Compared to LEED’s more prescriptive and quantitatively weighted structure, DGNB may offer a more balanced reflection of a building’s overall sustainability profile.

6.1.3 Mobility

The project received a maximum of one point in the Bicycle Facilities category. However, the project scored 0 points under the Reduced Parking Footprint credit. Under the Green Vehicles credit, the building earned 0.5 out of 1 point, indicating partial compliance, as shown in Figure 6.1. The building’s performance under LEED’s transportation-related credits reflects a selective alignment with sustainable mobility goals. While the project fully supports active transportation by earning the maximum points in Bicycle Facilities, it fails to score under the Reduced Parking Footprint credit and only partially complies with the Green Vehicles criteria.

In the technical Quality category, DGNB Mobility Infrastructure criteria are weighted at 2.2%, capturing broader dimensions of sustainable transport, including bicycle facilities, EV charging, and integrated access strategies. In contrast, LEED addresses these aspects through separate, lower-weighted credits: Bicycle Facilities (0.9%), Reduced Parking Footprint (0.9%), and Green Vehicles (0.9%), which combined total 2.7% weight, exceeding DGNB’s TEC3.1 Mobility Infrastructure (2.2%), as shown in Table 6.2.

Table 6.2 LEED and DGNB criteria weightage in LT and Mobility Infrastructure

% weightage	DGNB Credits	DGNB (category)	LEED Credits	LEED (category)	% weightage	
2.2	Mobility Infrastructure	Technical Quality	Bicycle Facilities	Location and Transportation	0.9	2.7
			Reduced Parking Footprint		0.9	
			Green Vehicles		0.9	

The underperformance in the Reduced Parking Footprint and Green Vehicles credits is primarily due to the differing assessment methods of LEED and DGNB. While DGNB evaluates parking reduction relative to locally required standards, LEED applies fixed thresholds irrespective of local context. Additionally, limited access to internal project data,

such as parking allocation and EV infrastructure, constrained full compliance with LEED documentation requirements.

Overall, the Troplo Daycare, a DGNB Platinum-certified building, achieved 10.5 out of a possible 12 points under the Location and Transportation criteria, indicating a strong alignment with LEED performance benchmarks, as shown in Figure 6.2.

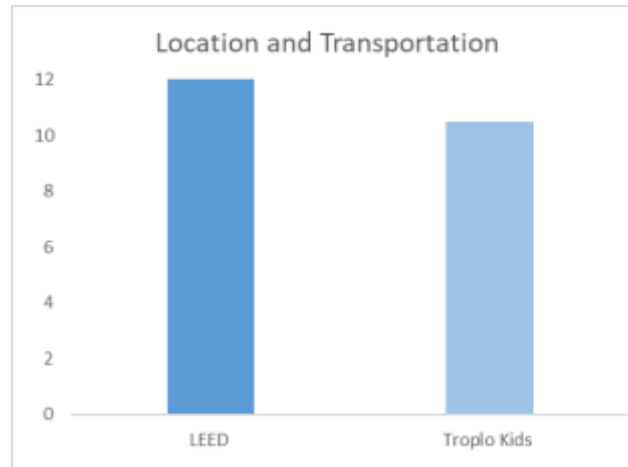


Figure 6.2 Score achieved by Troplo Kids Daycare against LEED v4 Location and Transportation Credit (LTc3-LTc7)(Author)

6.2 Sustainable Sites

6.2.1 Sustainable Site Features

The Troplo Kids earned a maximum of one point for Open Space and Site Assessment, as shown in Figure 6.3. This is supported by a thorough analysis using publicly available data sources such as Geoportal Hamburg and local climate databases. These resources allowed a detailed examination of the site's topography, hydrology, vegetation, human use, and public health factors. Although this assessment was not directly used during the design phase, it reveals how well the existing conditions align with LEED's sustainable development goals. The site maintains a high level of open space, with over 76% of the area remaining open and more than 30% covered by vegetation, excluding turf grass. The outdoor spaces were accessible and encouraged a variety of recreational and social activities, which contributed positively to the project's ecological and social sustainability.



Figure 6.3 Points obtained by each credit under Sustainable Sites under LEED v4 BD+C School (Author)

However, the building did not earn the Heat Island Reduction credit. Although strategies such as vegetated roofs and tree planting were implemented, the roofing materials failed to meet the Solar Reflectance Index requirements set by LEED. This represents a missed opportunity to mitigate urban heat effects, which are particularly crucial in dense urban environments for reducing local temperatures, lowering energy demands for cooling, and enhancing outdoor comfort.

Comparing LEED and DGNB frameworks reveals interesting differences in priorities. LEED assigns 1.8% weight to heat island reduction. In comparison, DGNB assigns a slightly higher weight of 3.1% to Biodiversity at the Site, suggesting a similar but somewhat broader focus on adapting to urban climate challenges. Moreover, DGNB places significantly more emphasis on the quality of indoor and outdoor spaces (4.2%) compared to LEED’s Open Space credit (0.9%), as shown in Table 6.3. This indicates that DGNB places greater emphasis on overall site quality and occupant experience.

Table 6.3 LEED and DGNB criteria weightage in subcategory of Sustainable Sites

% weightage	DGNB Credits	DGNB (category)	LEED Credits	LEED (category)	% weightage
2.5	Local Environment	Site Quality	Site Assessment	Sustainable Sites	0.9
4.2	Quality of Indoor and Outdoor Spaces	Socio-Cultural and Functional Quality	Open Spaces		0.9
3.1	Biodiversity at the Site	Environmental Quality	Site Development protect or restore habitat		1.8
	Biodiversity at the Site	Environmental Quality	Heat Island Reduction		1.8

The lower LEED score may stem from differences in assessment methods. While DGNB evaluates heat island mitigation through holistic quality levels and life cycle analysis, LEED relies on strict SRI thresholds. Although the building includes a green roof and shading elements, these may not meet LEED’s narrow criteria. Additionally, limited data on material

properties and reliance on tools like Geoportal Hamburg could have affected the accuracy of LEED-specific assessments.

6.2.2 Habitat Protection or Restoration

The Troplo Kid achieved one point out of two under the Protect or Restore Habitat credit, as shown in Figure 6.3. On successful restoration efforts, the project met the on-site restoration criteria by restoring approximately 37% of previously disturbed areas using native and adapted vegetation. However, it did not meet the minimum threshold of preserving 40% of the pre-construction greenfield area, achieving only 13.6% preservation. This partial compliance highlights the project's emphasis on restoring ecological function after disturbance rather than conserving existing natural habitats. In terms of environmental quality, Biodiversity at the Site in DGNB (3.1%) strongly relates to LEED's Site Development Protect or Restore Habitat (1.8%), as shown in Table 6.3.

The underperformance in the Preserve Habitat credit can be attributed to the urban context of Hamburg, where available land is typically already developed, leaving limited opportunity to preserve undisturbed greenfield areas. Although restoration efforts were successful, the preservation threshold was not met. Although DGNB places greater emphasis on biodiversity compared to LEED, the building's lower performance under LEED's Protect or Restore Habitat credit, despite achieving a Platinum DGNB certification, can be attributed to differences in evaluation approach and criteria specificity. Additionally, the area calculations were based on Geoportal Hamburg data and satellite imagery, which may not fully reflect pre-construction site conditions, as the project was built in 2014. This introduces a degree of uncertainty in the preservation estimates.

Overall, across the four Sustainable Sites credits evaluated, Troplo Daycare earned 3 out of a possible 6 points, as shown in Figure 6.4.

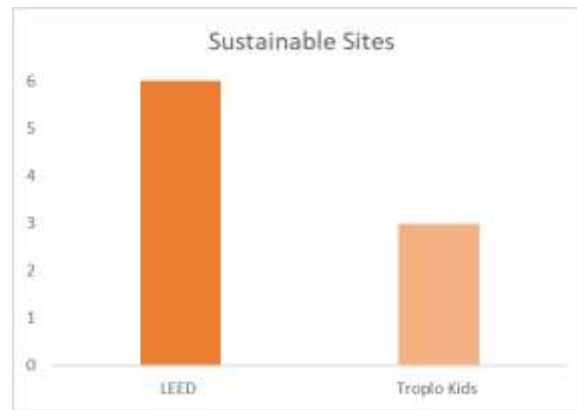


Figure 6.4 Score achieved by Troplo Kids Daycare under LEED v4 BD+C School (Sites Credit (SSc1-SSc3, SSc5) (Author)

According to the mini-rating scale based on LEED certification thresholds, the project falls within the LEED Platinum band, as shown in Figure 6.5. A total of 13.5 points were achieved out of the 18-point subset, resulting in a normalized score of 75%.

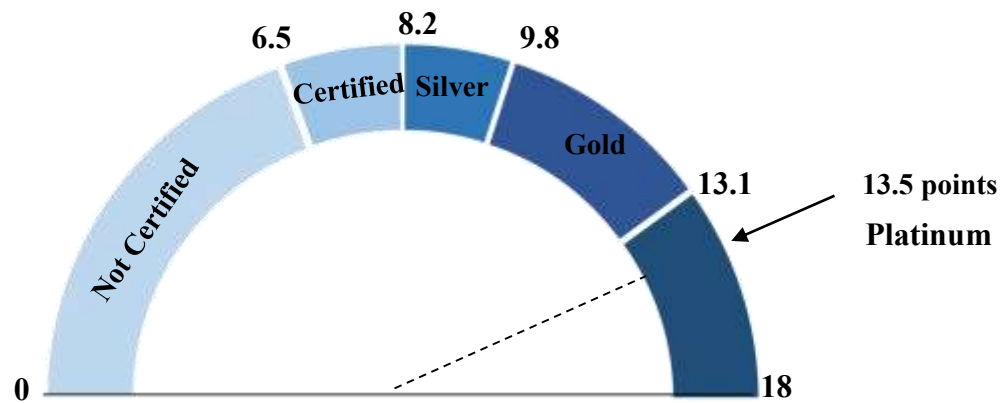


Figure 6.5 Troplo Kid Daycare Center Certification Level under LEED Mini Scale (Author)

The Troplo Kids Daycare project demonstrates a strong commitment to sustainable development, as evidenced by its achievement of LEED Platinum certification and DGNB Platinum certification. The LEED Platinum rating reflects above-average performance across key sustainability criteria, particularly in location and transportation, where the project excels due to its excellent transit accessibility, high surrounding density, and availability of diverse amenities. This rating signals that the building successfully integrates sustainable urban planning principles, promoting reduced car dependency and enhanced walkability.

While the project demonstrates partial compliance in areas such as Reduced Parking Footprint, Green Vehicles, and Heat Island Reduction, this is primarily influenced by differences in measurement criteria between LEED and DGNB, as well as the limited availability of project-specific data required for LEED documentation. Despite these challenges, the building still

achieves commendable scores, underscoring its strong and sustainable performance even under rigorous assessment frameworks.

The both systems are robust, but in different ways. The fact that a DGNB Platinum building can also meet LEED Platinum shows that DGNB's thorough, life-cycle approach can match or exceed LEED's standards, especially in high-performance design. The case study reveals that despite scoring low or zero in some individual LEED credits, the building still achieved a LEED-equivalent Platinum rating. This outcome highlights the flexibility of LEED's performance-based system, which allows strong performance in key areas to compensate for weaker ones. At the same time, it demonstrates the robustness of DGNB's holistic, life-cycle-oriented approach, as a project excelling under DGNB also aligns with LEED's highest standards.

6.3 Energy Performance

A key factor in achieving the energy efficiency goals is the thermal performance of the building envelope. Aligned with energy performance and energy optimization, this section synthesizes how specific material choices, wall thickness, and fenestration strategies contribute to reduced energy demand and improved environmental quality.

As highlighted by Ye and Ding (2025), enhancing the thermal characteristics of the building envelope is a critical strategy to lower operational energy use. This case study supports that assertion, demonstrating how low U-values, robust insulation thickness, and airtight construction significantly reduce heat transfer. Specifically, the opaque components exhibit an average U-value of just 0.16 W/m²K, while the transparent components (triple glazing) achieve 1.14 W/m²K, both of which are well below the thresholds set by the EnEV (2014) and GEG (2020) standards, as shown in the Table 6.4.

Table 6.4 A comparison of U- Values for Building Elements

Component	U Value W/m ² K (EnVE 2014)	U value W/m ² K (GEG 2020)	U value W/m ² K Troplo Kids
External Wall	0.24 Insulation 12 to 16cm	0.35	0.16 (Opaque elements)
Window	1.3 Double pane Thermal insulation Glazing	1.3	1.14 (Transparent element) Triple Glazing)
Flat Roof	0.20 Insulation with 16 to 20 cm	0.2	0.16 (Opaque elements)

These values confirm that the building's wall insulation and glazing system contribute directly to minimizing thermal losses. The role of thermal mass also contributes significantly to the building's energy performance. The reinforced concrete structural system acts as a thermal buffer, with a U-value of 0.16 for opaque elements, absorbing heat during peak hours and releasing it gradually, thereby smoothing temperature fluctuations. This illustrates how material properties influence indoor thermal stability.

An approximate Window-to-Wall Ratio (WWR) of the east and west façade shows a 100% WWR with triple-glazed frames. According to Gorantla, et al. (2021), triple-glazing systems are associated with reduced heat loss in winter and mitigated solar gain in summer regardless to window-to-wall ratio, contributing to lower HVAC loads and reduced greenhouse gas emissions. Similarly, Tang, et al. (2020) found that upgrading window systems to double or triple glazing led to considerable energy savings in existing residential buildings. In this case, the triple-glazed units not only contribute to thermal insulation but also enhance acoustic performance and reduce thermal bridging, which is particularly important in an educational context.

As Freewan (2014) demonstrated, the integration of fixed shading devices improves both daylight quality and indoor thermal comfort while reducing reliance on artificial lighting. The building's extruded frames and shading systems exemplify such passive strategies optimize the performance of window openings.

Furthermore, orientation plays a crucial role in energy performance. The east and west façades, with significant glazing, face high solar exposure in summer mornings and afternoons. However, the use of deep, extruded aluminum frames functions similarly to vertical and horizontal fins, reducing direct solar gains, glare, and interior overheating. These shading devices were also found to improve thermal comfort during operational hours (6:45 AM to 6:00 PM), highlighting the importance of synchronized design and usage patterns.

As supported by Liu, et al. (2023), deeper shading devices significantly reduce indoor temperatures in hot climates. This principle is evident here, where the façade geometry responds effectively to Hamburg's sun path, optimizing passive solar gain in winter and mitigating overheating in summer.

The use of a high-performance, ventilated façade system composed of powder-coated aluminum panels mounted on galvanized steel further reinforces the building's resilience and efficiency. The ventilated cavity acts as an air buffer, enhancing insulation and preventing

moisture buildup, a known contributor to long-term building degradation and energy loss. U-value requirements under GEG and EnEV effectively determine the thickness of walls required to achieve compliance.

The building achieves a final energy consumption of 84.7 kWh/m²/a, representing a 58.2% reduction compared to the EnEV 2009 reference value of 202.6 kWh/m²/a. In the context of LEED, energy performance is typically assessed using whole-building energy simulations in accordance with ASHRAE 90.1-2010, where the proposed building design is evaluated against a standardized baseline. Although a full simulation could not be carried out due to limited data availability, LEED awards up to 25 points to projects that demonstrate a 28% improvement in energy performance. Given that the subject building shows a 58.2% improvement based on EnEV criteria, it can be inferred that the project would likely perform exceptionally well under LEED's energy performance credit, potentially qualifying for the maximum available points in this category.

In conclusion, this study confirms that material properties, including insulation thickness, thermal mass, and façade composition, as well as window sizing, glazing type, and orientation, collectively impact the building's energy performance. The passive strategies embedded in the design, including shading, daylight optimization, and the coordinated use of thermal mass and airtight construction, illustrate how the architectural design of the building supports energy efficiency.

CHAPTER 7 CONCLUSION

In this study, the Troplo Kids Daycare, a DGNB Platinum certified building in Hamburg, was rigorously evaluated against selected LEED v4 BD+C criteria in the categories of Location and transportation, Sustainable Sites, and Energy Performance. The analysis demonstrated that the project performs exceptionally well in terms of transit accessibility and urban connectivity: with three high-frequency transit stops within 800 m, the building attains the maximum LEED points for Quality Transit (LTc4), and its proximity to a dense mix of amenities secures full credit for Surrounding Density and Diverse Uses (LTc3). These findings confirm that the site's urban context not only meets but exceeds LEED requirements for walkability and multimodal mobility, thereby significantly reducing the potential reliance on private vehicles and associated greenhouse gas emissions.

Regarding sustainable site stewardship, the project excels in providing generous, vegetated open space, with over 76 % of its site dedicated to accessible outdoor areas and more than 30 percent of those areas planted with diverse species earning full credit for Open Space (SSc3). A comprehensive site assessment (SSc1) also reveals that the campus's topography, hydrology, and human-use conditions support LEED-aligned planning. However, this was a reconstructive rather than a part of the original design process. However, shortcomings emerge in habitat preservation (SSc2) and Heat Island Reduction (SSc5). While on-site restoration of disturbed areas (37 %) surpasses LEED's 30 % threshold, only 13.6 % of pre-construction greenfield was preserved, and the absence of documented, high-reflectance roofing materials prevented compliance with heat-island mitigation requirements. Another important factor in low-scoring credit was the different assessment techniques used by LEED and DGNB. It is worth mentioning that DGNB does not rely on material SR or SRI value. Instead, it performs a Life Cycle assessment, which gives a more in-depth analysis of material behavior in the present and future as well.

In the realm of material and façade performance, the Troplo Kids facility demonstrates exemplary thermal characteristics: opaque components achieve a U-value of 0.16 W/m²K, and triple-glazed elements achieve a U-value of 1.14 W/m²K, both of which are well below the EnEV and GEG thresholds. The use of rear-ventilated aluminum cladding, deep extruded window frames, and exterior shading devices effectively balances daylight admission with solar control, validating the research hypothesis that material properties, wall assembly, and fenestration design are pivotal to energy efficiency. Although independent energy modeling

was constrained by data availability, secondary reports indicate a final energy consumption of 84.7 kWh/m²/a, substantially lower than regulatory requirements, underscoring the building's high-performance envelope and integrated HVAC and district heating systems.

Taken together, the building's proximity and service frequency of public transportation fully comply with LEED's Location and Transportation credits; its walkable access to diverse amenities strongly enhances connectivity; sustainable site features such as extensive open spaces, landscape plantings, and site assessments are well-incorporated; habitat protection is addressed primarily through restoration efforts but falls short of preservation targets; and the interplay of high-performance materials, wall thickness, glazing design, and passive shading strategies plays a decisive role in optimizing the building's energy performance.

From a DGNB perspective, the Troplo Kids Daycare excels in lifecycle performance, regional adaptability, and a balanced assessment of environmental, economic, and sociocultural quality, whereas LEED's point-based focus drove exceptional operational energy savings and transit-oriented design through clearly defined credit thresholds. In Germany and Europe, DGNB's holistic, context-sensitive framework often ensures deeper integration with local regulations and stakeholder needs, while LEED's prescriptive energy benchmarks and global recognition make it ideal for projects seeking straightforward documentation and broad market appeal.

Despite missing a few LEED credits, Troplo Kids' DGNB Platinum rating reflects its deeper, life-cycle and context-driven sustainability strengths areas LEED's credit-by-credit approach does not fully capture. While LEED highlights specific performance targets (e.g., green-vehicle parking), DGNB rewards holistic integration of materials, user comfort, and urban fit. Thus, DGNB's Platinum status signals comprehensive, long-term sustainability in a European context, rather than undermining the building's environmental reliability.

7.1 Limitation

This study is limited by restricted access to primary data, such as on-site measurements, detailed architectural drawings and energy simulations, due to privacy constraints. Consequently, the assessment of energy performance relied on qualitative analysis of secondary sources, including architectural and technical documentation. Additionally, only one DGNB Platinum-certified building was analyzed, which may limit the generalizability of the findings. The study also does not attempt a complete comparison between DGNB and LEED systems due to their methodological differences, focusing instead on selected LEED criteria, which

narrows the scope of the evaluation. It is recommended that DGNB and LEED credit categories addressing the same sustainability objectives be systematically mapped and normalized to a standard metric before evaluating any case study.

DECLARATION OF AUTHORSHIP

I hereby declare that the attached Master's thesis was completed independently and without the prohibited assistance of third parties, and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

Berlin, 04.07.2025

Location, Date



Signature of the student

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