DIPLOMARBEIT

Thermal Comfort Analysis of Allotment Garden Dwellings in Vienna: A Case Study

unter der Leitung von

Univ.-Prof. Dipl.-Ing. Dr.techn. Ardeshir Mahdavi

E 259-3: Abteilung für Bauphysik und Bauökologie

Institut für Architekturwissenschaften

eingereicht an der

Technischen Universität Wien

Fakultät für Architektur und Raumplanung

von

Jessica Parizek

01225236

Gisela-Legath-Gasse 1/3/12, 1220 Wien

Wien, März 2021

ABSTRACT

The public interest in the ecological and environmental benefits of allotment gardens has been increasing in the past few years. However, they rarely appear in political and media discourse even though allotment gardens represent a large membership with a rising desire for high quality living. Nowadays allotments do not only consist of these private gardens but also of small simple dwellings, which are more and more often used for year-round living. Therefore, the significance of the indoor environment is increasing, but the normative background is still insufficient as most allotment regulations concentrate on the heterogeneous appearance of the building and its placement on the large private parcels.

Consequently, the thermal comfort of five different existing allotment garden residences is researched in this thesis in greater detail. These allotment gardens, all located in Vienna, vary from single-family homes to summer accommodations during daytime and were built at different construction periods. In general, allotment gardens are mostly used during the summer period and four of these five dwellings were originally planned for summer usage only. For that reason, the investigation period was picked to be the summer season. The houses were monitored for three months measuring both temperature and relative humidity. The measurements were taken from the most frequently used rooms in each house: the living rooms and bedrooms. Further, the outdoor temperature was monitored as well as each allotment was exposed to different environmental conditions. The measured data was compared to Austrian Standard Criteria and Thermal Comfort Indices. For further analyses the risk of summer overheating was simulated.

Findings show that these five allotments have a great variety in temperature and relative humidity performances. The four houses originally planned for the summer period only, show acceptable results for the summer time, but indicate a decreasing thermal comfort at lower outside temperatures. Thus, adjusted ventilation controls as well as exterior shadings would be recommendable to further improve the thermal comfort during the summer period. Only the newest allotment, built in 2009, KLG Hagedorn House 3, shows most measurement values within the wanted comfort window ranges, as it was originally planned for the year-round usage and contains an air conditioning unit in the main bedroom.

Keywords

Indoor environment conditions, Summer overheating, Community gardens, Psychrometric analysis

ACKNOWLEDGEMENTS

Firstly, I would like to thank my supervisors, Univ. Prof. Dipl.-Ing. Dr. techn. Ardeshir Mahdavi and Associate Prof. Dipl.-Ing.(FH) Dr. techn. Matthias Wilhelm Schuß for their expertise, guidance and support. Further, I would like to thank the allotment garden dwelling owners, as they welcomed me into their homes, supported me with all their knowledge about allotments and helped me during the monitoring process within the study period.

Finally, I would like to give a special thanks to my family, friends and colleagues for their unconditional support, encouragement and advice.

CONTENTS

1 INTRODUCTION

1.1 Overview

The density of buildings in urbanized areas has increased worldwide. The same trend can be seen in Vienna as the inner-city densification, the loss of green space and higher temperature differences between the city and the surrounding areas can be observed (Urban Heat Island Strategy, City of Vienna, 2018). Urban gardens or community gardens guarantee the achievement of environmental and societal goals. The gardens help with water regulation, local climate, health and social cohesion. Therefore, the number of community gardens has multiplied within the past decades. As a result, allotment gardens, with their history of more than one hundred years, combine the benefits of community gardens with private parcels. Still, in today's society in Vienna these dwellings often do not only consist of summer cottages but small year-round used family homes. As people tend to spend more and more time within buildings, the indoor environment demand is rising.

1.2 Motivation

Due to the small building volume, to low room heights or to an infrastructure difficult to access, allotment garden houses can be differentiated from regular single family houses. Whilst there is plenty of data to the overall building physics performance of single family houses, scientific research for allotments often refers to the positive environmental aspects only. Still, the demand for allotment garden dwellings should not be based on their positive environmental outcome. The study '*Characteristics and motivations of potential users of urban allotment gardens: The case of Vila Nova de Gaia municipal network of urban allotment gardens*' (Martinho da Silva, Oliveira Fernandes, Castiglione, Costa, 2016) describes the motivation behind the increasing number of urban allotment gardens in Portugal, which results in the usage of recreation areas, access to independent farming or environmental concerns. Accordingly, the demand of allotment garden dwellings is still increasing in today's society all over Europe.

The overall energy consumption of buildings depends on factors as heating, cooling, ventilating and lighting. Still, these indoor environment indices affect the comfort, health and productivity of each occupant as they are applied according to the occupant's actions and demands (ÖNORM EN 16798-1, 2019). "*There is therefore a* *need for specifying criteria for the indoor environment for design and energy calculations for buildings and building service systems.*" (ÖNORM EN 16798-1, 2019)

So, on one hand the significance of thermal comfort is on the increase, but on the other hand allotment garden dwellings still suffer from an insufficient normative background and are primarily defined by their structure and cubature prescribed in the legal regulation for allotment gardens. Further, allotment gardens are mostly associated with urban greening rather than building physics. Nevertheless, building physics and ecology also encompass the relationship of the indoor environment with ecological green surroundings.

A precise analysis of a sample of five allotment residences and their thermal comfort can provide data about indoor comfort assessments with heterogeneous structures and in a green environment. The satisfaction with a private outdoor environment is meaningless without a positive thermal sensation indoors. Therefore, this master thesis is a case study of the thermal comfort performance of five different allotment houses.

1.3 Background

1.3.1 History of Allotment Garden Dwellings in Vienna

The history of allotments started with the German doctor Daniel G. M. Schreber and his thoughts of enhanced green spaces during the industrialization of 1840. He died before realizing his dream. In memory of him the school principal Dr. Ernst I. Hauschild implemented it within the '*Schreberverein*' in Leipzig (Kral 1992). He built a playground and called it '*Schreberplatz*'. His successor Heinrich C. Gesell started creating gardens which later became urban recreation areas (Autengruber 2018). These allotments with their characteristic name '*Schrebergärten*' evolved to a role model for other leisure garden movements.

The first allotment association in Vienna was founded by Julius Straußhügel in 1909, which positioned their first garden plots in Rosental in today´s 14th district of Vienna (Autengruber 2018). The Industrialization caused an immense population growth and a rather restrictive life for the Viennese working class. As a result, allotment garden dwellings formed a response to a decreasing space to live as well as to food shortage. The exploitation of natural resources was important during both world wars. In the meantime many wild garden dwellings as well as recent allotment dwellings, generated by the City Council, developed at the borders of the city.

During the 1960s the main factor of food provision shifted to a reserve for building land. Thus, many gardens have fallen victim to other construction projects. In the 1980s the importance shifted again back to recreation areas as originally planned in Leipzig (Autengruber 2018). As the demand of leisure gardens was still high while the number of garden dwellings was slowly decreasing, the project '*Aktion 2000*' was formed in 1983. For the first time since 1945 new allotments should be built in Vienna (Kral 1992). Unfortunately, since 2000 the number of new allotment associations in Vienna has decreased again, whereas new dwellings are still planned across Austria. From 1926 until today the *Office International du Coin de Terre et des Jardins Familiaux* has linked the interests of allotment garden dwellings worldwide.

1.3.2 Development of building requirements

In 1920 the legal conditions of Viennese allotment garden dwellings only included the non-commercial usage of any cultivated natural resources. Since 1929 they have been part of the Viennese planning scheme (Autengruber 2018). The first federal law for allotments was announced in 1959. The first Viennese law for allotment garden dwellings called '*Wiener Kleingartengesetz*' was announced two months later. Whereas the federal law did not change much, the '*Wiener Kleingartengesetz*' changed significantly. The first version of this law denotes that the minimum length of each garden has to be at least 10m and only small summer cottages of 25m² maximum could be built on each property. It was permitted to use these cottages from April 15th to October 15th (Gesetz über Kleingärten in Wien, 1959). Since 1978 these cottages can be built up to an area of 35m² (Gesetz über Kleingärten in Wien, 1978).

As the importance of leisure gardens and their impact as recreation areas shifted, the Viennese law for allotment garden dwellings started to shift as well. In the '*Wiener Kleingartengesetz*' version of 1992 the possibility of living within allotment houses was given at last. Houses could be built up to a maximum of 50m² or 25% of the garden area (Gesetz über Kleingärten in Wien 1992). Therefore, the development plan of Vienna started using two terms: EKL (allotment houses) and EKLW (allotment houses for year-round living).

In 1996 the version we largely use nowadays was implemented. But still no provisions according to thermal insulation, sound insulation or fire protection were required. These aspects only changed in 1999 with a modification of the Viennese allotment garden law of 1996. It was described that allotment houses had no regulations according to thermal or sound insulation, whereas allotment houses for year-round living had to fulfil an U-value of 0,5[W/(m²K)] for exterior walls, roof constructions and floors of recreation rooms against the ground. Sound insulations as stated in the Viennese building insulations were not in need of fulfilment (Landesgesetzblatt für Wien, Wiener Kleingartengesetz, 1999). Since 2014 energy certificates and evidence of sound insulation have been required for allotment houses for year-round living (Landesgesetzblatt für Wien, Wiener Kleingartengesetz, 2014).

1.3.3 Current building requirements

Austrian allotment gardens can hold an area of 120m² to 650m². Lease agreements can be signed for an indefinite period or for a definite period of at least 10 years. Each individual can possess one allotment garden per state only (Bundesgesetz über die Regelung des Kleingartenwesens, 1958).

In Vienna each garden should at least include an area of 250m² up to 650m². These gardens should represent areas of recreation and living. To emphasize this exploitation the gardens should at least be 10m wide and 2/3 of the garden must be landscaped. Allotment associations should include a minimum of two allotment gardens, which can contain cottages or houses depending on their dedication to the Viennese planning scheme (Wiener Kleingartengesetz, current version 2020). The cottages should contain a distance of 2m to traffic areas, 2.5m to paths and 3.5m to passable roads. The distance to bordering properties should be 2m, except when the building is only 3m high and contains no windows to the neighbouring facade. Further, this wall has to be fire resistant (Kuzmich, MA19, 2016). The dedications of EKL (allotment houses) and EKLW (allotment houses for year-round living) still exist have been in use since 1992.

Allotment houses can be placed on allotment gardens (EKL) or temporary allotment gardens (temporary EKL) and should include one common room. This common room is only meant to be a place of retreat. Dedications for temporary allotment houses can contain a gross area of 16m² or a maximum of 25% of the total garden area. Typical allotment houses (EKL) can contain a gross area of 35m² or a maximum of 25% of the total garden area. Temporary EKL can be built to a height of 4.2m while not exceeding 50m³ gross volume. Otherwise EKL should not be built higher than 5m and can hold a maximum volume of 160m³. Basements on EKL can contain a gross area of maximum 58m² (Kuzmich, MA19, 2016).

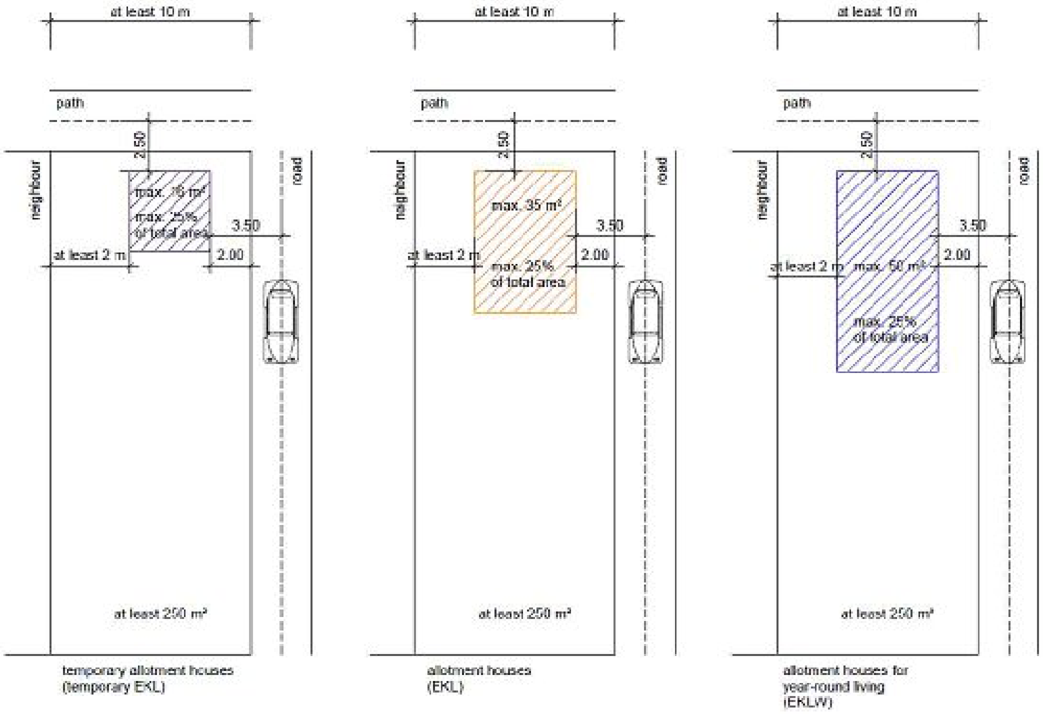


Figure 1: Current requirements for temporary EKL, EKL and EKLW

Houses for year-round living on EKLW should also include at least one main room and should be used to satisfy the overall housing needs. The maximum constructed area can be 50m² as seen in Figure 1. The houses can be built with a maximum gross volume of 265m³ and a height of 5.5m. Basements should not exceed an area of 83m² (Kuzmich, MA19, 2016).

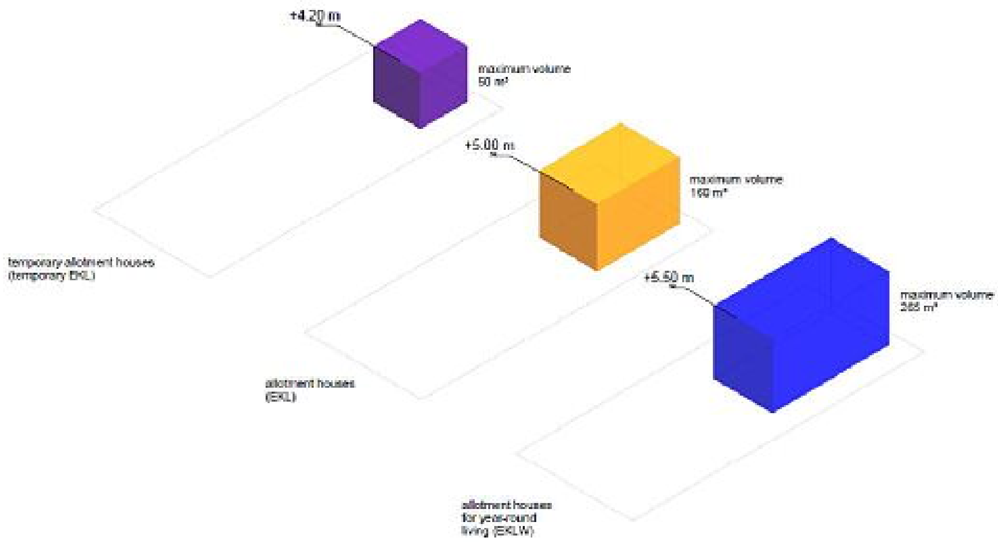


Figure 2: Construction volume of temporary EKL, EKL and EKLW

All these buildings should correspond to the typical character of allotment garden dwellings, including their colour, shape and overall appearance. Therefore, eaves can be only built to maximum of 0.7m. Balconies will not be included into the overall gross area if they do not exceed an overhang of 1.2m. Terraces can be built up to an area of 2/3 of the buildings total gross area. Lightweight roofing for these terraces can include 25% of the obscured area (Kuzmich, MA19, 2016).

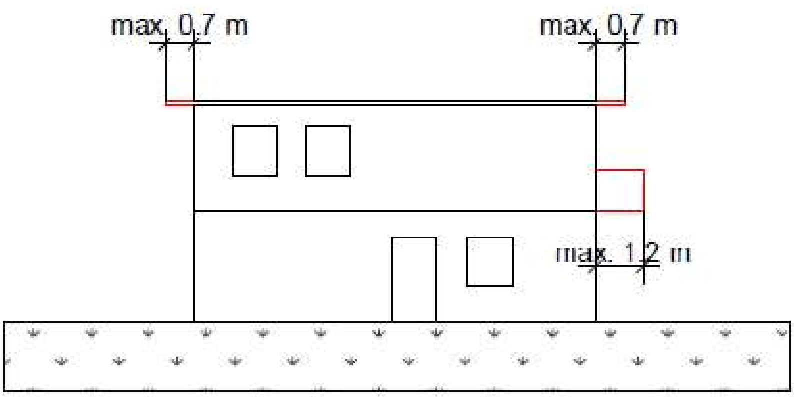


Figure 3: Maximum overhang for balconies and eaves

Within the planning permission procedure for temporary EKL, EKL and EKLW the construction plans should include the position and size both within the dedication area and the property. Further, the height of the building and the overall cubature has to be shown in a construction plan of the whole facade (Wiener Kleingartengesetz, current version 2020).

Overall, the current building requirements for allotment houses focus on similar heterogeneous structures, which allow an extended use of the garden areas rather than complex architectural designs.

1.3.4 Comfort

"Comfort is typically defined as a condition of mind that expresses satisfaction with the surroundings." (Hens, 2012) Thus, the overall comfort for a human being depends on thermal, acoustical and visual comfort.

Humans have a core temperature of around 37°C. As the outside temperature is often lower than our core temperature, we lose heat due to radiation, convection, evaporation and conduction. Humans lose approximately 50% of heat by radiation, 25% by convection, 15% by evaporation and a small amount due to conduction (Riccabona, 2003). For that reason, humans are influenced by factors as air temperature, relative humidity, relative air velocity and radiant temperature to fix the heat exchange and consequently create thermal comfort.

Young adults are able to hear sound frequencies between 20 and 16 000 Hz. As a result, humans are sensitive to a lot of sounds surrounding them (Hens, 2012). *"Undesired noises such as neighbours, traffic, industry and aircraft will disturb people, generate complaints and often create long-lasting disputes."* (Hens, 2012) Accordingly, acoustic comfort is also a part of the overall comfort in a person's daily life.

Humans are physically able to see electromagnetic waves with wavelengths between 0.38 and 0.78 µm. Depending on these colour schemes, humans can be affected both physically and mentally. Still, visual comfort mostly depends on the factor of glare control, due to the sensitivity of the human eye to great luminance contrasts.

"*Overall thermal comfort and the assessment of indoor environmental quality do not depend solely on physical parameters. The human body's physiological and psychological responses to the environment are dynamic and integrate various physical phenomena that interact with the space (light, noise, vibration, temperature,* *humidity, etc.).*" (Rupp, Vásquez, Lamberts, 2015) This thesis focuses on the thermal comfort including temperature and relative humidity.

1.3.4.1. Thermal Comfort

To maintain thermal balance of a human's body, thermal sensation has to be created by different factors of daily life. These factors can be divided into the following groups: environmental, personal or contributing factors (Auliciems, 1997). Environmental factors include air temperature, air movement, humidity and radiation. We are exposed to these factors, but we can partly influence them in our indoor environment. Personal aspects can be described by the metabolic rate, which is measured in met and our clothing, measured in clo. These are the factors which can be easily influenced by changing the activity rate or tending to less or more clothing, therefore a lower or higher clo value. Contributing factors can differ from person to person as they include acclimatization, body shape, age, gender and the state of health (Auliciems, 1997). "*Overall, a precondition of human well-being in terms of both productivity and health, appears to be the achievement of a harmonious balance between minimization of physical responses (that is, the state that we subjectively interpret as thermal "comfort"), and maximization of acclimatization*." (Auliciems, 1997)

"*Thermal neutrality for a person is defined as the condition in which the subject would prefer neither warmer nor cooler surroundings.*" (Fanger, 1970) As a result, thermal neutrality is a part of thermal comfort. In most cases, thermal comfort and thermal neutrality will show similar results (Fanger, 1970). So it is used to define comfort zones. However, a person who is in a state of thermal neutrality does not necessarily have to feel comfortable with their surroundings. Other factors as past experience, habits, expectations or socio-cultural factors can be involved (Auliciems, 1997).

It is impossible to satisfy everybody, even when achieving thermal comfort or thermal neutrality. Nevertheless, you can predict the possibility of acceptance by an approximate percentage of people (ÖNORM EN ISO 7730, 2006). "*Within the area of human performance, there is some evidence to suggest that moderate thermal stress may actually lead to improved performances in schools and within factories with heat acclimatized workers, but in general, exposure to discomfort leads to loss of capacities for physical and mental work.*" (Auliciems, 1997)

1.3.4.2. Current thermal comfort requirements

For allotment garden dwellings the recommended norm indoor temperature for living rooms and bedrooms lies at 20°C as stated in the ÖNORM H 1283-1 (2018). The temperature range for heating season lies between 20 and 25°C for a clo of 1.0 and a sedentary activity for 1.2met. The temperature range for the cooling season lies between 23 and 26°C with 0.5 clo (ÖNORM EN 16798-1, 2019).

During the permission process, evidence for thermal insulation for allotment houses for year-round living has to be given (Wiener Kleingartengesetz, current version 2020). Thus, these buildings or parts of the building should be planned considering the state of the art and shown by the submission of the energy certificate (Bauordnung für Wien, current version 2020).

By assessing the comfort performance of buildings, the overall performance and predictions of uncomfortable phenomena such as summer overheating are summarized into a single value or category (Carlucci, 2013). According to the OIB guideline 6, the summer thermal insulation is given when no risk of summer overheating is present or no cooling demand is needed. The risk of summer overheating has to be presented as part of the energy certificate for new buildings. As the energy certificate is now part of the planning permission process, the risk of summer overheating needs to be presented for allotments for year-round living. Neither temporary EKL nor EKL need to fulfil thermal insulation guidelines or need a guarantee against summer overheating.

2 ALLOTMENT HOUSES DESCRIPTIONS

2.1 KLG Hagedorn, House 1

The *KLG Hagedorn House 1* lies in the allotment association Hagedorn in the 22nd district of Vienna which was founded in 1991. Today the association includes 112 parcels and is surrounded by other allotment clubs. The overall environment is primarily used for arable land and residential areas.

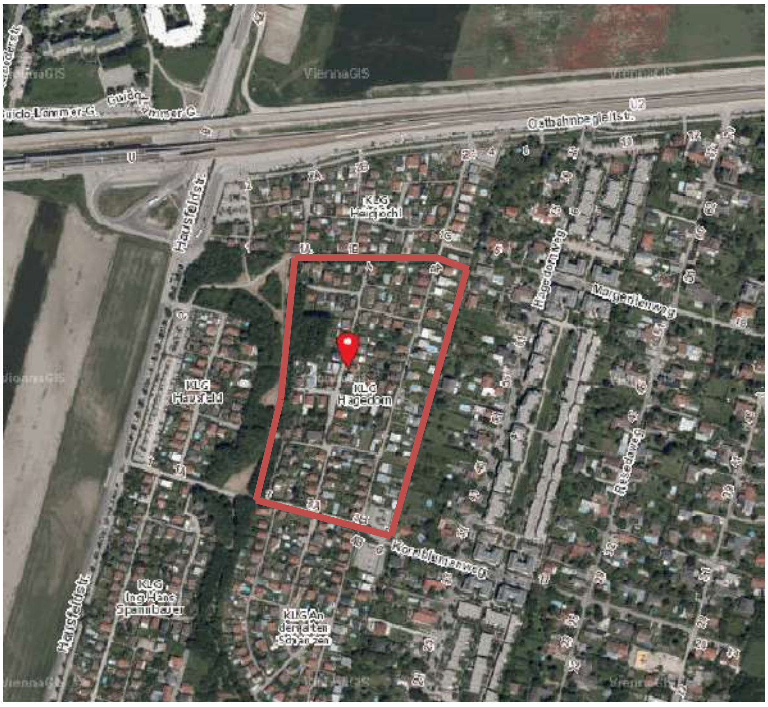


Figure 4: Aerial photo of the KLG Hagedorn (Wien.gv, 2020)

In 2013 the expansion of the U2 subway network improved the infrastructure at the *KLG Hagedorn* significantly. Not only the subway but trams and buses are available in a close range around the association, which makes it easy to access the city as well as close surroundings. Either educational institutions or shopping facilities can be accessed within a range of 2km.

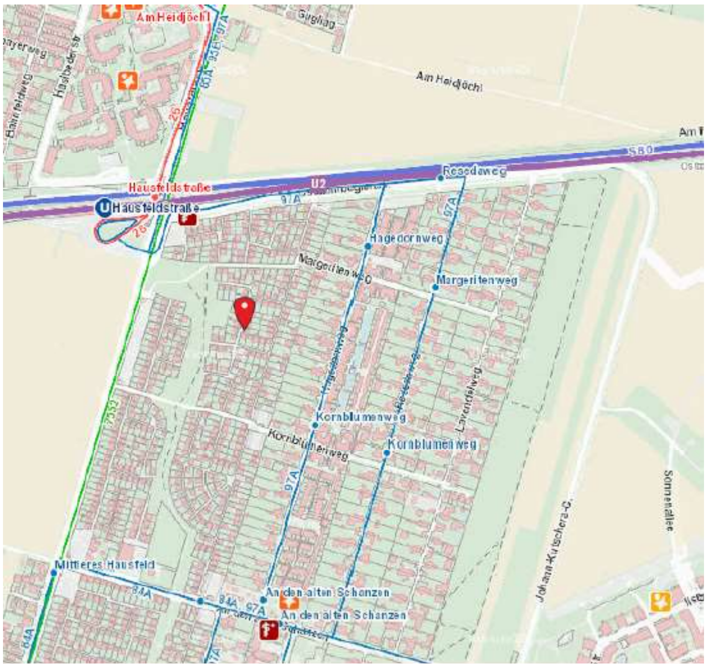


Figure 5: Aerialphoto of the infrastructure at KLG Hagedorn (Wien.gv, 2020)

KLG Hagedorn House 1 has a dedication of EKLW, which allows the owners to use it for year-round living. Nevertheless, the house is only used on a few occasions during daytime in summer. Further, it was ventilated during the whole period by tilted windows at the bedrooms. The terrace door to the living room stayed open when the house was used or was opened during daytime at high temperatures by the neighbours. During winter the allotment house is rarely used and only heated by a gas heating system occasionally.

The construction was started in 1991 and finished in 1993. In 1999 an anteroom was supplemented. Further, the facade was refurbished by adding 5cm of insulation to the massive brick construction. In 2005 another reconstruction took place, as a second bedroom was constructed on the first floor.

Overall, the house consists of a massive brick construction for exterior walls of 25cm and 5cm insulation, as well as interior walls of 10 to 25cm bricks. The mansard roof was built with a rafter roof construction with mineral wool and concrete roofing tiles. The slab from the heated basement to the ground consists of PAE-foil, 25cm concrete, 5cm XPS, PAE-foil, screed and tiles, whereas the interior slabs consist of 25cm concrete, 3cm EPS, screed and parquet flooring. The basements walls were built of 30cm concrete. The windows are all double thermal insulation glasses.

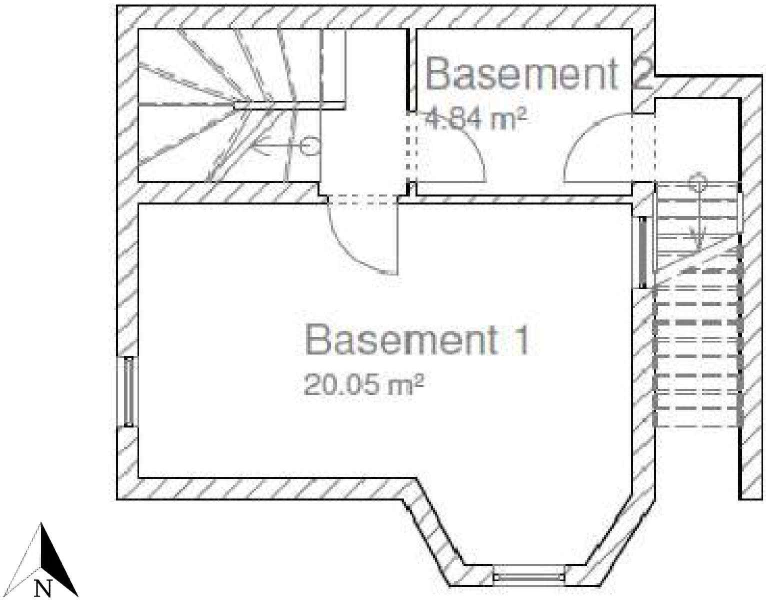


Figure 6: Heated basement of KLG Hagedorn House 1

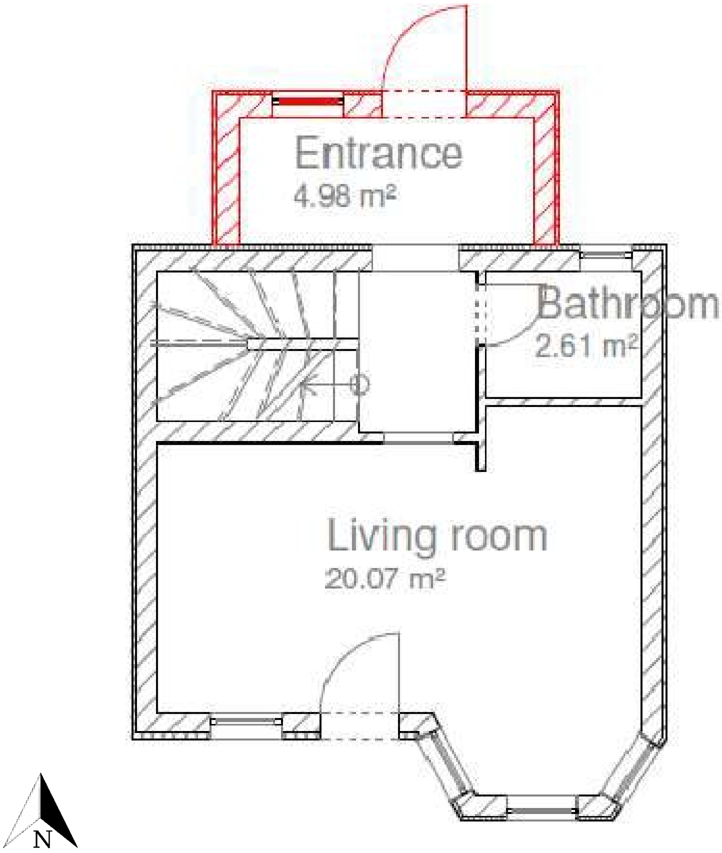


Figure 7: Ground floor of KLG Hagedorn House 1

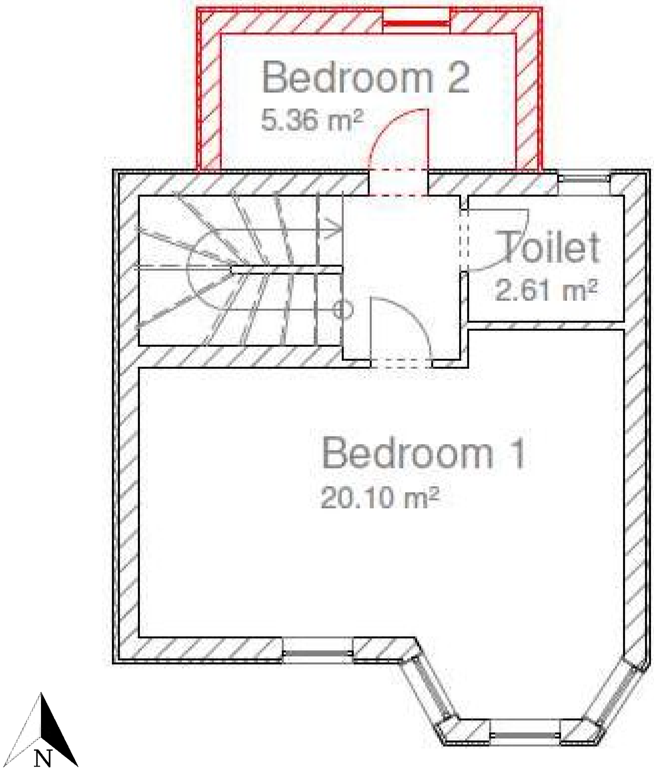


Figure 8: First Floor of KLG Hagedorn House 1

The house includes one living room, an anteroom and a bathroom on the ground floor on 44.6m² of gross area. The room height is 2.2m with windows of 80/100cm and a glass door on the south facade. The old parts of the building which contain the living room and the bathroom lie directly above the heated basement. The basement is nearly 25m² big with a room height of 2.2m. It has not been refurbished yet. From the cellar the garden is directly accessible by a roofed staircase at the east facade. The first floor contains two bedrooms, one facing south and one north, as well as a toilet with an overall gross floor area of 44.6m². The room height of the first floor is about 2.1m, reducing to 1.35m at the edges of the mansard roof. The overall height of the house is 5m.

2.2 KLG Hagedorn, House 2

KLG Hagedorn House 2 is a neighbouring building to House number 1 and therefore underlies the same circumstances of infrastructure and environment.

House 2 was originally planned for the summer usage only but nowadays has the dedication of allotment house for year-round living and is used by the owners as their primary residence. Accordingly, the house is often ventilated during summer period and heated by a gas heating system during winter time.

The start of construction was in 1991. The house was finished in 1993 in a massive brick construction with 5cm insulation. In 1997 the entrance on the ground floor and a bedroom on the first floor were added, both facing west. In 2003 the basement under the terrace was extended, which increased the basements gross area by 26.1m². In 2005 the roof was changed from a mansard roof to a pent roof with a slope of 3% as seen in Figure 12.

Overall, the house consists of a similar construction as *KLG Hagedorn House 1*. It was built with a massive brick construction for exterior walls of 25cm and 5cm insulation, as well as interior walls of 10 to 25cm. The roof nowadays consists of a pent roof with wooden rafters and wooden slats as well as 20cm of insulation in between. The basements walls were built of 30cm concrete. The slab from the heated basement to the ground consists of PAE-foil, 25cm concrete, 5cm XPS, PAE-foil, screed and tiles, whereas the interior slabs consist of 25cm concrete, 3cm EPS, screed and carpet. The windows are all double thermal insulation glasses.

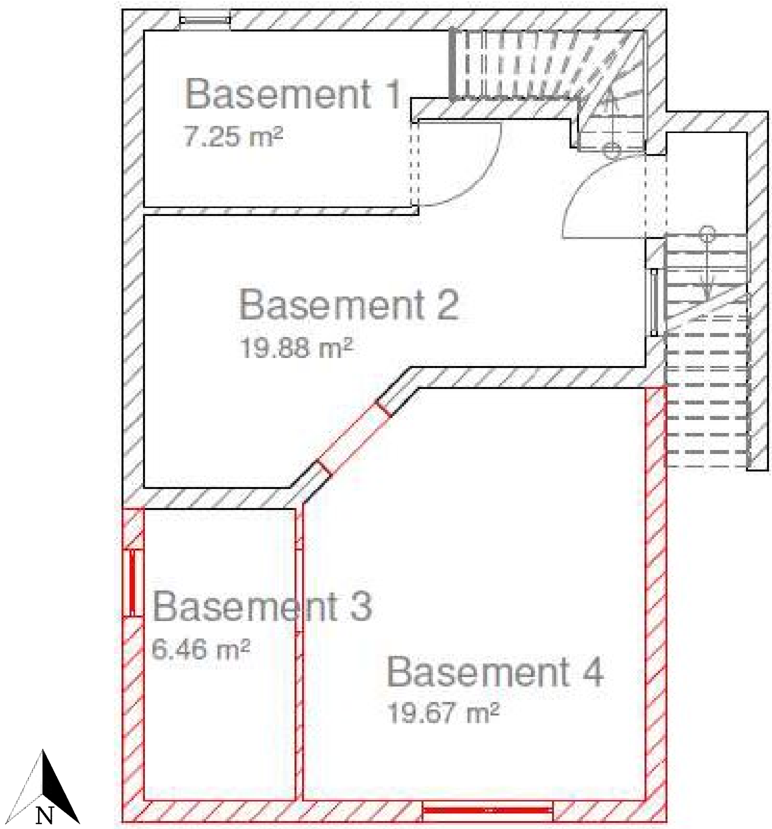


Figure 9: Heated basement of KLG Hagedorn House 2

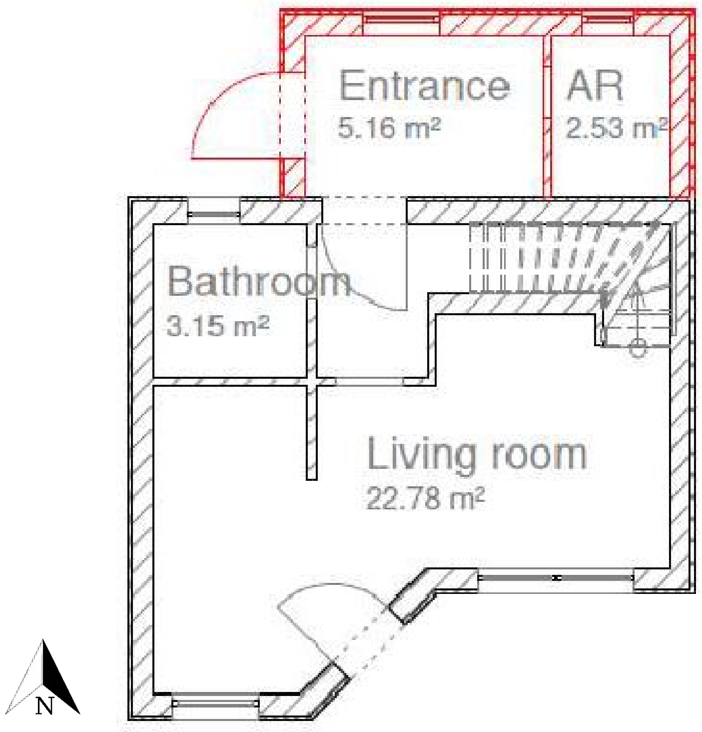


Figure 10: Ground floor of KLG Hagedorn House 2

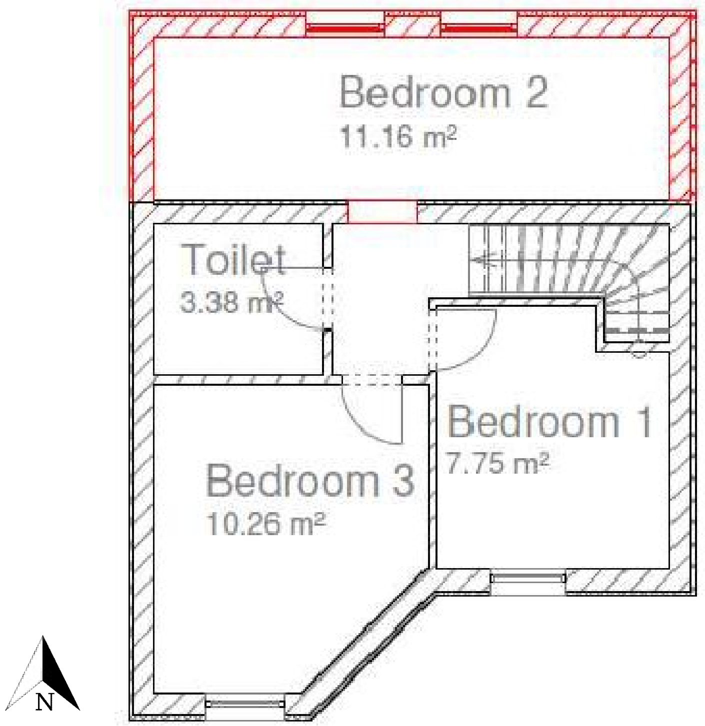


Figure 11: First floor of KLG Hagedorn House 2

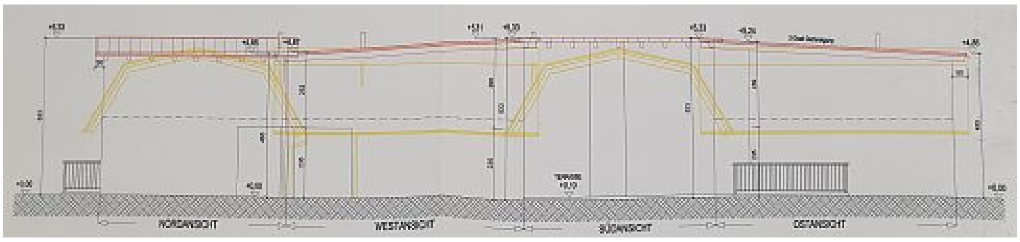


Figure 12: Conversion from mansard roof to a flat roof

The heated basement lies under half of the ground floor area, including four rooms. The ground floor consists of a living room with an integrated kitchen facing south, a bathroom and an anteroom with an included storeroom on overall 44.5m². The room height is 2.2m. The first floor now consists of three bedrooms and a toilet. Two of these bedrooms face south, whereas the third one faces north. Since the roof was modified to a flat roof the room height is about 2.9m at the highest point. Overall the house is 5.3m high.

2.3 KLG Hagedorn, House 3

As well as *House 1* and *2*, *KLG Hagedorn House 3* lies at a neighbouring property to these two allotments. It also has the same dedication of EKLW and was originally planned by the owners as their primary residence since it was built in 2009. Prior to 2009 a wooden cottage, which was built in 1993, stood at the houses place. The House is consistently ventilated and also heated by an under-floor heating system during the winter period. Further, the house has an air conditioning system in Bedroom 1 as the owners perceive the Bedroom 1 as too hot during night in the summer period.

KLG Hagedorn House 3 was built with a massive construction of exterior walls of 25cm Porotherm and 7cm Lambdapor, as well as interior walls of 10 to 25cm bricks. The roof was constructed as a pent roof of timber formwork with 20cm mineral wool in between. The slab to the unheated basement consists of 6cm Isover insulation, 18cm concrete, 6cm EPS, screed and parquet, whereas the interior slabs consist of 18cm concrete, 6cm EPS, screed and parquet. The windows are all double thermal insulation glasses.

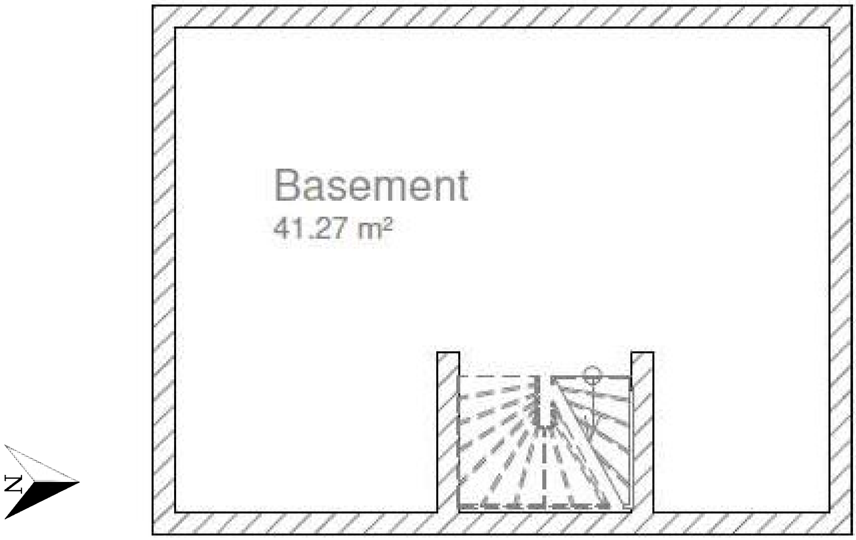


Figure 13: Unheated basement of KLG Hagedorn House 3

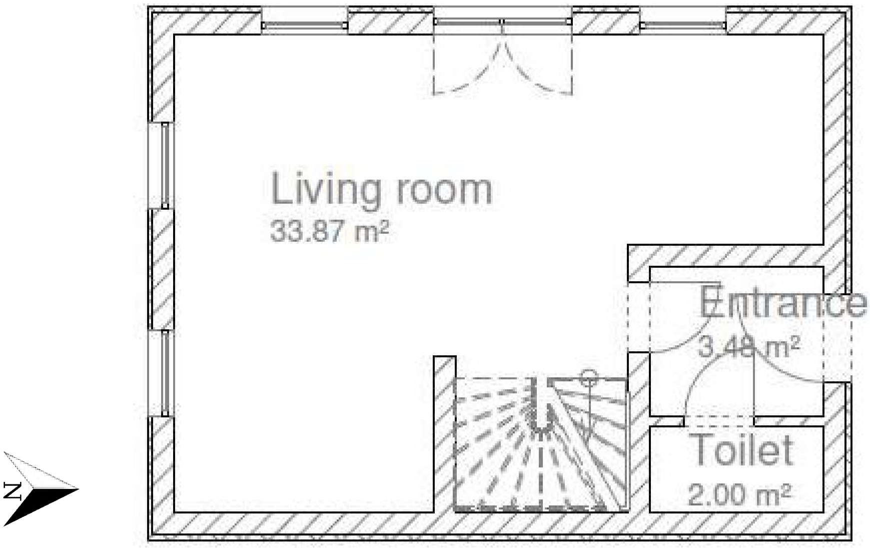


Figure 14: Ground floor of KLG Hagedorn House 3

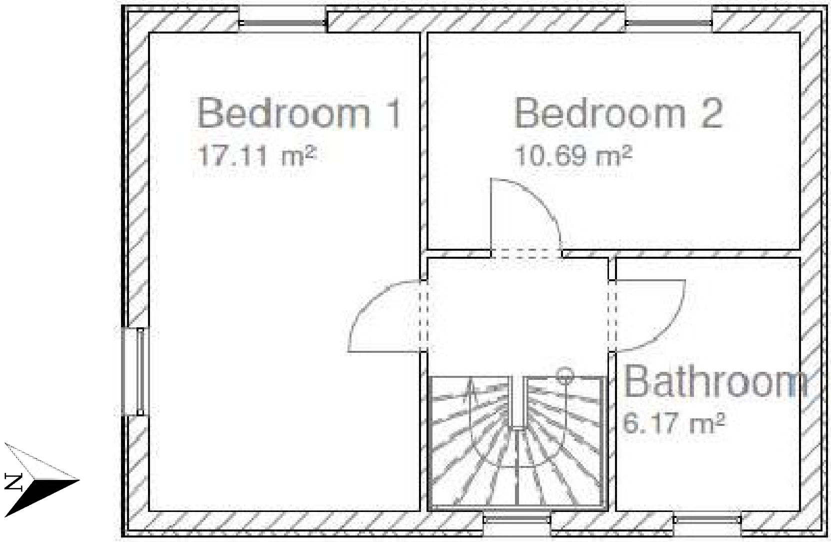


Figure 15: First floor of KLG Hagedorn House 3

The unheated basement has 41.3m² gross area and lies completely under the ground floor. The ground floor includes a living room with a kitchen of 33.9m² facing both west and south as well as small entrance and a toilet. The first floor has two bedrooms and one bathroom. The room height on each floor is 2.3m, whereas the overall height of the building lies at 5.4m.

2.4 KLG Eschenkogel

The allotment association *KLG Eschenkogel* was formed in 1983 in the 10th district of Vienna. It contains 95 parcels. The association lies in close proximity to other allotment associations at the so called '*Wienerberg*'. The surrounding area consists mostly of residential buildings and recreation areas.

Figure 16: Aerialphoto of the KLG Eschenkogel (Wien.gv, 2020)

The infrastructure consists mostly of buses and tramways which can be reached within a distance of 1km. Public establishments are rather easy to access.

Figure 17: Aerialphoto of the infrastructure at KLG Eschenkogel (Wien.gv, 2020)

The house *KLG Eschenkogel* was built as a wood construction in 1988. The dedication is EKLW which allows it to be used as a primary residence for the entire year. Therefore, it is both ventilated and heated when necessary. In 2009 the living room and the bathroom were expanded by 12.2m². In that process the walls were refurbished as 10cm of insulation was added.

Therefore, the house now exists of a 20cm timber frame construction with an insulation of 15cm mineral wool in between. The exteriors walls also contain 10cm EPS insulation since 2009. The interior walls consist of gypsum boards. The gabled roof consists of a 38cm thick timber frame construction including 20cm of mineral wool. The slab from the heated basement to the ground consist of PVC-foil, 25cm concrete, 5cm XPS, PVC-foil, screed and tiles, whereas the interior slabs consist of 25cm concrete, 3cm EPS, screed and parquet flooring. The basements walls were built with 30cm concrete. The windows are all double thermal insulation glasses.

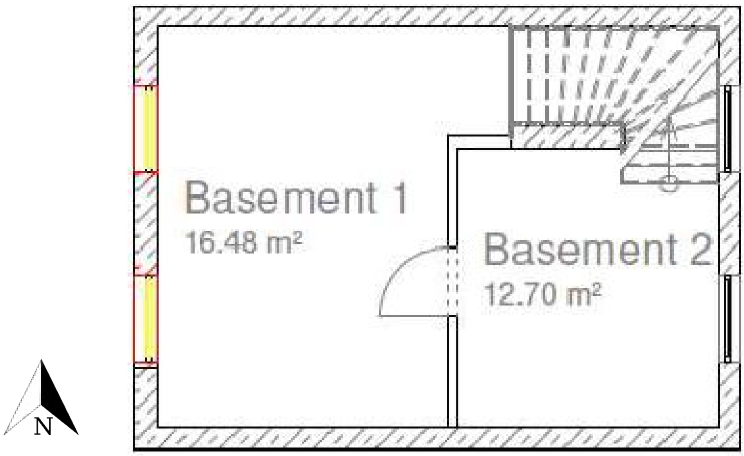


Figure 18: Heated basement of KLG Eschenkogel

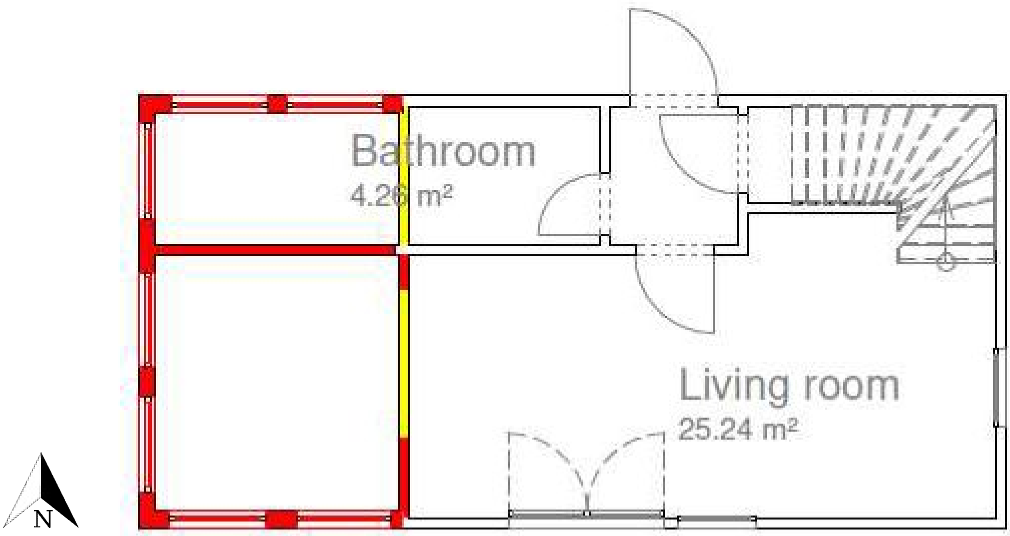


Figure 19: Ground floor of KLG Eschenkogel

Figure 20: First floor of KLG Eschenkogel

The heated basement of 29.2m² lies directly under the old built-up area and includes two rooms. The ground floor consists of a 33.7m² living room, a 7.96m² bathroom and a small entrance area. From the living room the terrace at the south side of the building can be reached by a glass terrace door. The room height is 2.3m. On the first floor two bedrooms can be found both having windows facing south. The overall height of the building is 5m at the top point of the gabled roof.

2.5 Temporary KLG Klagergrube

The *temporary KLG Klagergrube* lies in the 22nd district of Vienna and has been used as temporary KLG since 1965. The properties surround a pond and lie in between farmland, which has been a part of the building ban explained at the area to protect the environment.

Figure 21: Aerial photo of the temporary KLG Klagergrube (Wien.gv, 2020)

As a result of the building ban stated at the area, no residential or public buildings can be found at the immediate surroundings. Further, the infrastructure makes the area hard to access. Due to the building ban, no official association was formed and the properties can be only used as temporary allotments. As a result, no constructions with a gross area of more than 16m² are allowed.

The cottage at the *temporary KLG Klagergrube* was built in 1965 as a 12,5cm timber frame construction without any exterior insulation. The pent roof consists of only 8cm timber frames. Overall, the cottage has only one room which is placed directly under two huge trees. The room has one window and one door, both facing north which are opened the whole day when the cottage is used during the summer period. The window is constructed of a double thermal insulation glass. Even in the summer months, the allotment is only used during daytime. In 2008, a tiny storage room was added at the west facade. The allotment is 2.5m high, whereas the storage room is only 2m high. During winter the cottage is not used at all as it has no heating system.

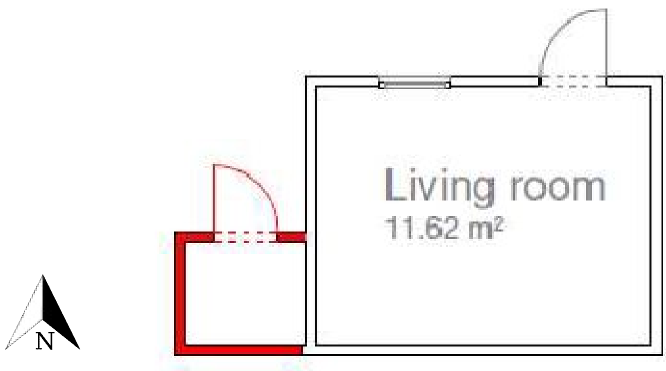


Figure 22: Ground floor of temporary KLG Klagergrube

3 METHOD

3.1 Overview

During this master thesis the five allotment garden dwellings were studied in greater detail. All of them are distributed across Vienna and were accessible during the study period. Over a period of three months, from the beginning of July to the end of September, the temperature and the relative humidity were monitored by data loggers described in 3.3.1 placed in the most frequently used rooms: living rooms and bed rooms as seen in 3.4. for specific locations. These measurements were used to determine the physical neutrality and comfort levels. To calculate the tendency for summer overheating the software *Archiphysik 17.0* was used.

3.2 Study Period

As allotment garden dwellings have their primary usage during summer and two of the five allotments are not used as a primary residence the study period was selected to be from July to September. Further, the possibility of summer overheating of these allotments is another aspect of this study. Consequently, the summer period shows the most influential results to this prospect. The measuring devices were placed and removed on different dates according to the accesses to each of the allotments.

3.3 Equipment used

3.3.1 Onset HOBO U12-012 Data Logger

The Onset HOBO U12-012 Data Logger is a measurement device for temperature, relative humidity, light intensity and can be used as an internal as well as an external data logger. According to the data sheet the supported measurements are 4-20mA, AC Current, AC Voltage, Air Velocity, Carbon Dioxide, Compressed Air Flow, DC Current, DC Voltage, Gauge Pressure, Kilowatts (kW), Light Intensity, Relative Humidity, Temperature and Volatile Organic Comp. According to the manufacturers the 12-bit resolution provides a high accuracy. The measurement range for temperature lies between -20°C and 70°C, for the relative humidity between 5% and 95% RH and for the light intensity 1 to 3000 foot candles. Between

0 to 50°C the temperature accuracy lies at +/- 0.35°C. The accuracy for the relative humidity lies at +/- 2.5% from 10 to 90% RH.

Figure 23: Onset HOBO U12-012 Data Logger

Within this study the values of temperature and relative humidity were collected with the Onset HOBO U12-012 Data Loggers with a selected sampling rate of 5 minutes. The data was offloaded with a direct USB interface and exported via the compatible HOBOware.

3.4 Data Logger Locations

The data loggers were placed as seen in Figure 24 to Figure 32. Also, four loggers were placed within weather shields nearby the houses *KLG Hagedorn House 1*, *KLG Hagedorn House 2*, *KLG Eschenkogel* and the *temporary KLG Klagergrube* to monitor the outside temperature and relative humidity as further described in 3.5.

3.4.1 KLG Hagedorn, House 1 Logger Locations

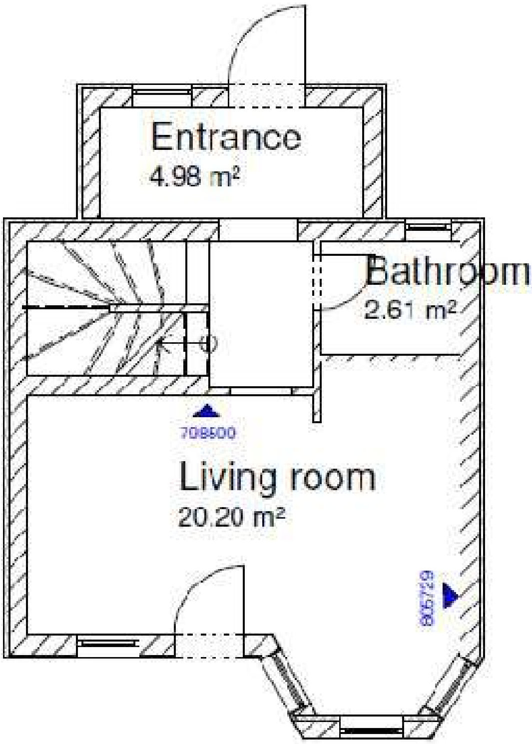


Figure 24: Plan of the ground floor of KLG Hagedorn, House 1 showing the data logger locations

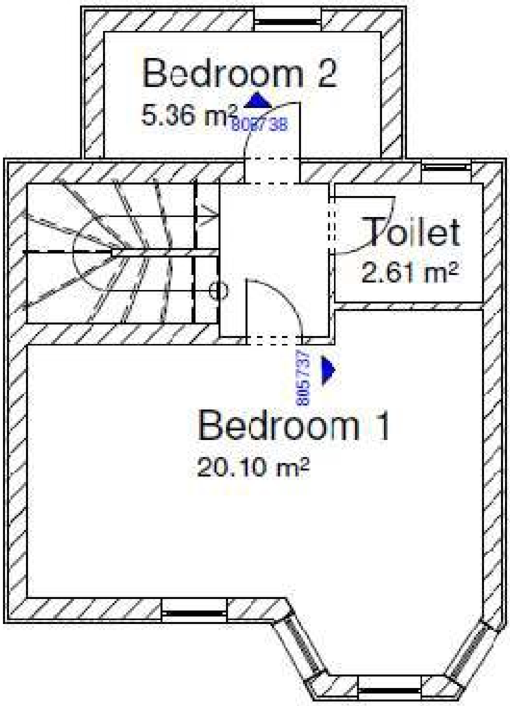


Figure 25: Plan of the first floor of KLG Hagedorn, House 1 showing the data logger locations

3.4.2 KLG Hagedorn, House 2 Logger Locations

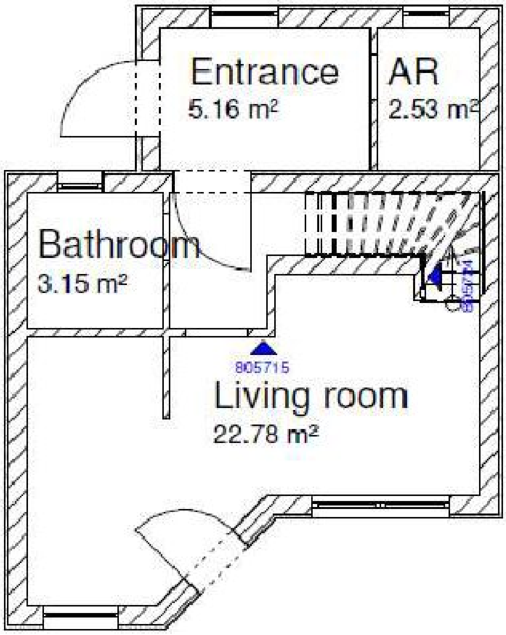


Figure 26: Plan of the ground floor of KLG Hagedorn, House 2 showing the data logger locations

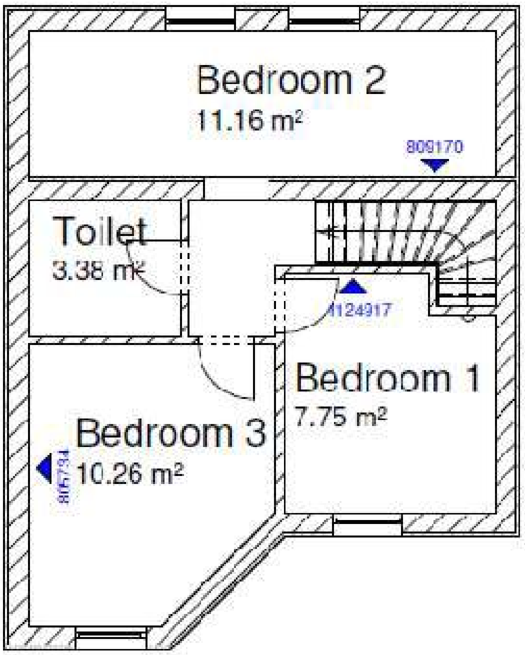


Figure 27: Plan of the first floor of KLG Hagedorn, House 2 showing the data logger locations

3.4.3 KLG Hagedorn, House 3 Logger Locations

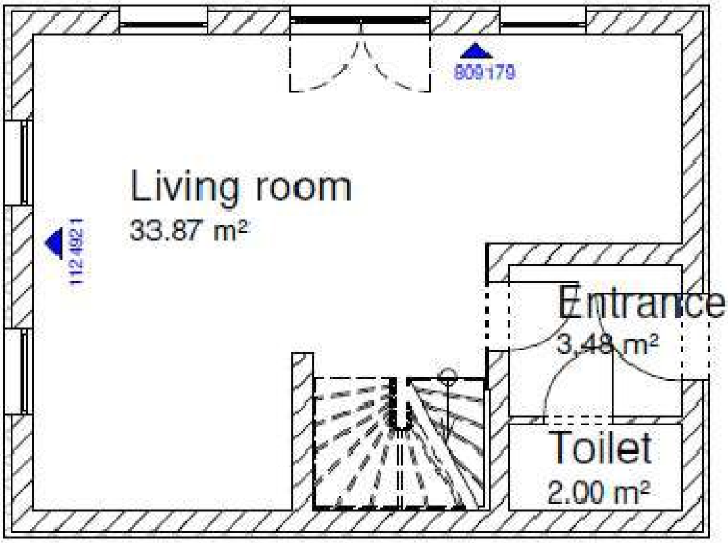


Figure 28: Plan of the ground floor of KLG Hagedorn, House 3 showing the data logger locations

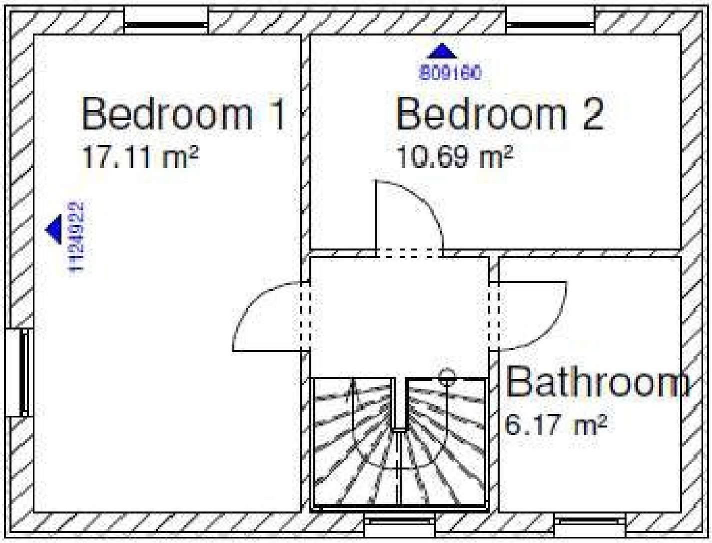


Figure 29: Plan of the first floor of KLG Hagedorn, House 3 showing the data logger locations

3.4.4 KLG Eschenkogel Logger Locations

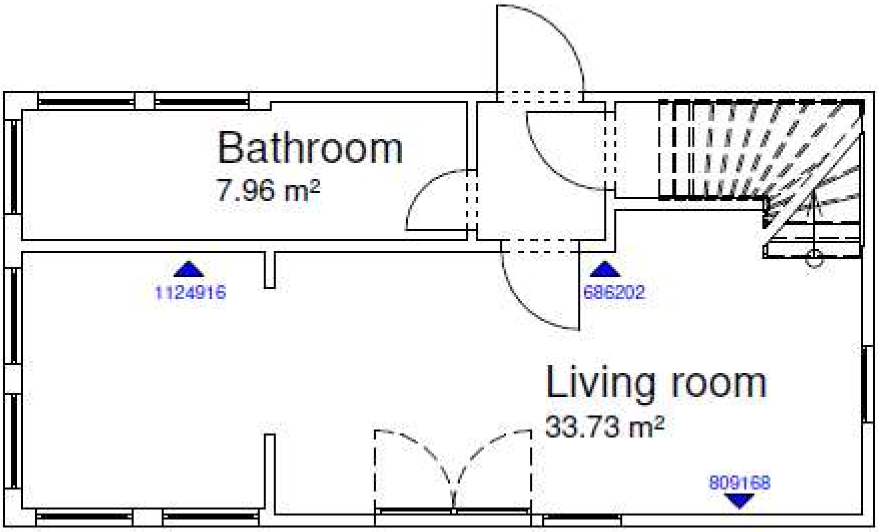


Figure 30: Plan of the ground floor of KLG Eschenkogel showing the data logger locations

Figure 31: Plan of the first floor of KLG Eschenkogel showing the data logger locations

3.4.5 Temporary KLG Klagergrube Logger Locations

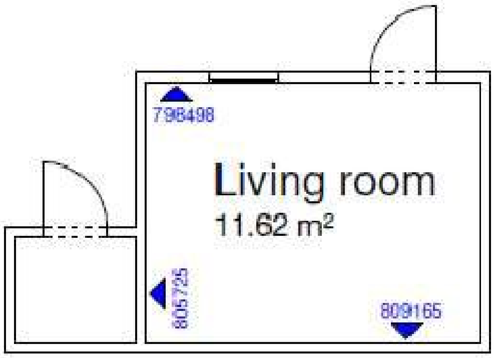


Figure 32: Plan of the ground floor of the temporary KLG Klagergrube showing the data logger locations

3.5 Weather Data

The weather data is monitored during the whole study period for four of the houses: *KLG Hagedorn House 1*, *KLG Hagedorn House 2*, *KLG Eschenkogel* and the *temporary KLG Klagergrube* with the HOBO U12-012 inside weather shields as seen in Figure 33. These '*shields*' were placed in the gardens a few meters away from the houses and were exposed to a similar shading as the allotments themselves. The outside loggers monitored the temperature and relative humidity the same way as the inside loggers. In the following figures the monitored weather data is compared to the monitored data of the weather station of the Technical University in Vienna.

Figure 33: Weather shield for Onset HOBO Data Loggers used to record outside conditions

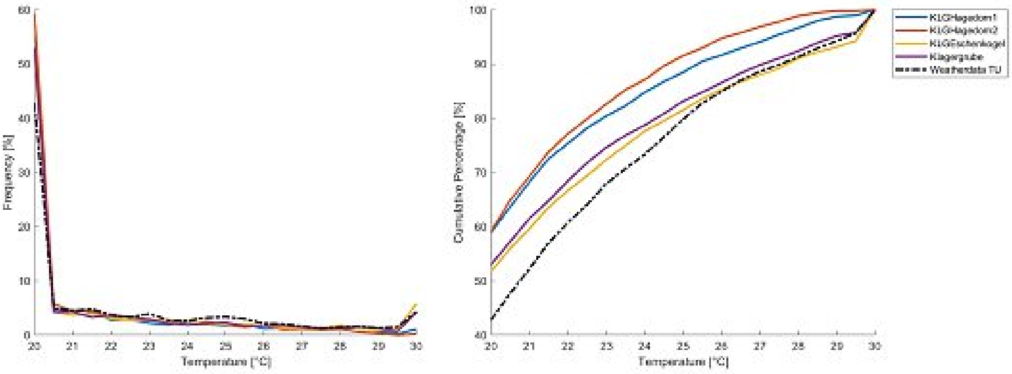


Figure 34: Temperature profile for the whole study period of the weather data: temperature bins (left), cumulative temperature distribution (right)

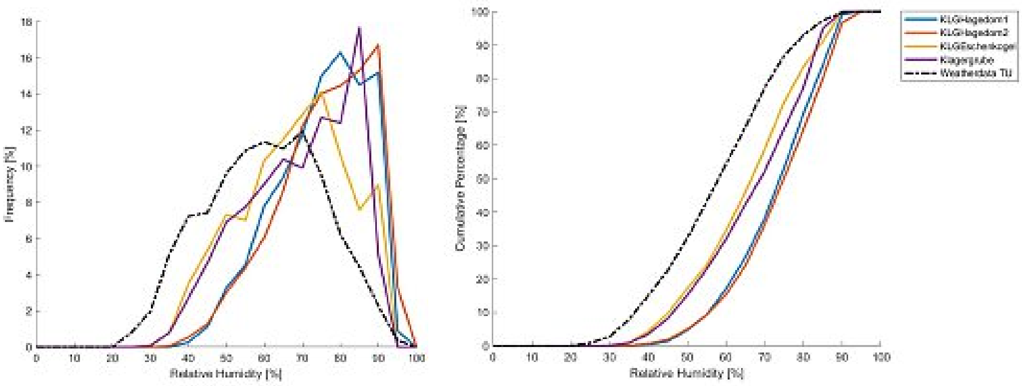


Figure 35: Relative humidity profile for the whole study period of the weather data: relative humidity bins (left), cumulative relative humidity bins distribution (right)

As both the temperature and the relative humidity perform slightly different at all '*shields*' the inside data is compared to the weather data for each allotment separately and not with an exterior weather data set. As the *KLG Hagedorn House 3* is a neighbouring building of *KLG Hagedorn House 2*, the weather data set of *KLG Hagedorn House 2* is also used for *KLG Hagedorn House 3*. For graphs comparing all five houses the weather data of *KLG Hagedorn House 2* is used, as four of the five houses are distributed in the 22nd district of Vienna and three of them are neighbouring properties.

3.6 Thermal Analysis

The data from the loggers was analyzed using *Matlab*. The monitored interval of five minutes was standardized to 15 minutes steps and analyzed for the whole period of study as well as for each month separately. The data is illustrated for each house and each usage category separately. The first category is '*Living rooms*' as the main rooms of each house, which also includes the main room of the *temporary KLG Klagergube*, as this allotment only exists of this room. The second category called '*Bedrooms 1*' shows the main bedrooms of the four allotments for year-round living. The third category called '*Bedrooms 2*' includes bedrooms which are mainly used as guest rooms.

3.6.1 Data logger Analysis

The Data logger Analysis is broken down into two parts: the temperature analysis and the relative humidity analysis. Each part shows the results of all loggers in all allotment garden dwellings for the whole study period. Further, the monthly results are illustrated for the following usages: living rooms and both categories of bedrooms. Accordingly, the data is illustrated as temperature or relative humidity bins as well as cumulative distributions.

3.6.2 Thermal Comfort

3.6.2.1. Thermal neutrality

As described in chapter 1.3.4.1 thermal neutrality is similar to thermal comfort. Different reviews show the dependence of thermal neutrality on the outdoor temperature. This neutrality temperature is applicable for people at sedentary work in a common environment. Further, the clothing is self determined. These temperatures are valid between 18 and 30°C (Auliciems, 1997). The neutrality temperature was calculated as in Formulae (1):

$$Tn = 17.6 + 0.31 \times Tm \qquad (1)$$

T_n Neutrality temperature [°C]

T_m Mean outside temperature of the month [°C]

The range of acceptable comfort conditions for T_n lies between +2.5 and -2.5°C (Auliciems, 1997). Within these comfort conditions 90% of people view the temperature as neutral (Szokolay, 2014).

The measured air temperature values of the living rooms of all five allotment garden dwellings were compared to the neutrality temperature range for each month and each house separately.

3.6.2.2. Psychrometric Analysis

Psychrometric charts show the relationship between dry bulb temperature and specific humidity as well as the correlating relative humidity lines. The horizontal axis shows the dry bulb temperature in °C, whereas the vertical axis shows the moisture content or absolute humidity measured in grams of moisture per kg dry air. As air can only hold a certain amount of water vapour, the relative humidity curves are included as well. The top curve shows the saturation humidity, where the air is 100% saturated. The comfort zone was created by using the side boundaries of the neutrality temperature range of acceptable comfort conditions as described in 3.6.2.1 (Auliciems, 1997). These side boundaries of Tmin and Tmax were taken separately according to their calculated neutrality temperature ranges for each month as well as each allotment garden dwelling. For the upper and lower limit, the relative humidity limits were taken as 20% and 80% as stated in the ASHRAE Standard 55, 2017. The measured data was then be compared to the calculated comfort zone and described by the percentage of points outside the comfort zone. This percentage was split into two parts: the percentage of points lower than Tmin and the percentage of points higher than Tmax.

3.6.2.3. Summer Overheating Analysis

The risk of summer overheating shows a possibility of discomfort during the study period. Further, it has to be presented during the permission procedure of newly built allotment garden dwellings for year-round living. Therefore, it was simulated with *Archiphysik 17.0* for all five allotment garden dwellings.

During the simulation of the risk of summer overheating the most critical room of each building has to be picked. For *KLG Hagedorn House 1* Bedroom 1 was picked as it is facing southwards. At *KLG Hagedorn House 2* Bedroom 3 was used for the calculation as it has the highest storage capacity of construction components and faces south. For *KLG Hagedorn House 3* Bedroom 1 was picked as its walls face south, east and west and is also described as the room with the highest potential for summer overheating by the owners. At *KLG Eschenkogel* Bedroom 2 was picked for the calculation process as it has a minimal higher storage capacity of the construction components. As the *temporary KLG Klagergrube* consists only of one room this room was picked for the summer overheating calculation.

Two methods of simulation procedure are possible to use with *Archiphysik*. One works as the old standard suggested: with the calculation of the storage capacity of the construction components (Battisti, Somogyváry, 2018). The detailed method for the simulation is described in the ÖNORM B8110-3 (2020), which is the method that is used within this master thesis.

According to the standard the following factors had to be included in the simulation process: orientation of the room, usage of the room, storage capacity of the construction components, the components orientation, shadings and the used ventilation method, especially during night time. The structure of the building components of all houses were implemented in *Archiphysik* by the descriptions of the inventory plans and the descriptions of the owners. Further, the operative temperature were calculated and compared to the outside temperature of July 15th. The operative temperature is "*the uniform temperature of an imaginary black enclosure, and the air within it, in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual nonuniform environment*." (ASHRAE Standard 55, 2017) Therefore, the operative temperature cannot directly be compared to the air temperature, as the air temperature is slightly higher. The limits of 25°C during night and 27°C during day should not be exceeded by the operative temperature (ÖNORM B8110-3, 2020).

Within both simulations of the rooms of *KLG Hagedorn House 1* and *KLG Hagedorn House 2* the windows were able to open during night and have average interior shadings. *KLG Hagedorn House 1* further has a 20° overhang over the windows due to its roof construction. *KLG Hagedorn House 3* is also ventilated during night, but has very well-functioning exterior shading. Bedroom 2 of *KLG Eschenkogel* is naturally ventilated during night but has no shading as well as no overhang. The room of the *temporary KLG Klagergube* is never used overnight. For that reason, no ventilation during the night time is possible. Dark exterior shading is applied to the window.

As predicting uncomfortable phenomena as summer overheating are summarized into a single value or category (Carlucci, 2013) the risk of summer overheating is categorized into different quality classes: not suitable for summer, conditionally suitable for summer, suitable for summer, well suited for summer and very suitable for summer (ÖNORM B8110-3, 2020).

4 RESULTS AND DISCUSSION

4.1 Measurements

For each allotment garden the measurement period was slightly different as they were accessible during different times. In Table 1 the start and end date of each measurement period is illustrated. The analyzed data was picked to be from July 14th to September 30th.

Table 1: Measurement period of each data logger

	Start Date	End Date
KLG Hagedorn House 1		
#805729	30.06.2019	26.10.2019
#798500	30.06.2019	26.10.2019
#805737	30.06.2019	26.10.2019
#805738	30.06.2019	26.10.2019
#8091701	13.07.2019	26.10.2019
KLG Hagedorn House 2		
#809170	04.07.2019	07.10.2019
#1124917	04.07.2019	07.10.2019
#805734	04.07.2019	07.10.2019
#805715	04.07.2019	07.10.2019
#805724	13.07.2019	07.10.2019
#809154	13.07.2019	07.10.2019
KLG Hagedorn House 3		
#1124921	04.07.2019	03.10.2019
#809160	04.07.2019	03.10.2019
#1124922	04.07.2019	03.10.2019
#809179	04.07.2019	03.10.2019
KLG Eschenkogel		
#1124919	09.07.2019	05.10.2019
#1124923	09.07.2019	05.10.2019
#994109	09.07.2019	05.10.2019
#686202	09.07.2019	05.10.2019
#809168	09.07.2019	05.10.2019
#1124916	09.07.2019	05.10.2019
Temporary KLG Klagergrube		
#809164	06.07.2019	07.10.2019
#798498	06.07.2019	07.10.2019
#805725	06.07.2019	07.10.2019
#809165	06.07.2019	07.10.2019

4.2 Data logger results

In each allotment garden dwellings between three and five inside loggers were monitoring both temperature and relative humidity. These loggers were distributed over fourteen study areas, including living rooms, bedrooms and the main room of the *temporary KLG Klagergrube*. The bedrooms will be divided into two sections: Bedroom 1 and Bedroom 2. *'Bedroom 1'* is always the main bedroom, whereas '*Bedroom 2*' includes guest rooms. As the living rooms were monitored by several loggers, the following logger were chosen for the representation of the data within the monthly sections of *'Living rooms'*: #798500 for *KLG Hagdorn House 1*, #805715 for *KLG Hagedorn House 2*, #809179 for *KLG Hagedorn House 3*, #686202 *KLG Eschenkogel* and #8085725 for the *temporary KLG Klagergrube*. The summary results of the study period from July 14th to September 31st 2019 are illustrated below. These results were compared according to the usage of the room: either for living rooms or bedrooms. As the *temporary KLG Klagergrube* only consists of one room, this room was compared to the other living rooms.

4.2.1 Temperature

Figure 36 to Figure 49 show the temperature bins and the cumulative temperature distribution for each allotment garden for the whole study period and for each usage in each month. According to the ÖNORM EN 16798-1 the temperature range for the cooling season lies between 23 and 26°C.

4.2.1.1 Temperature profile of each allotment

The temperature profiles of all loggers of each allotment garden dwelling are illustrated in Figure 36 to Figure 40. Further, each monitored outside temperature is included. The outside temperature is portrayed as a black broken-dotted line. The upper and lower temperature limits of 23 and 26°C, as stated in the standard, are illustrated as grey dashed lines.

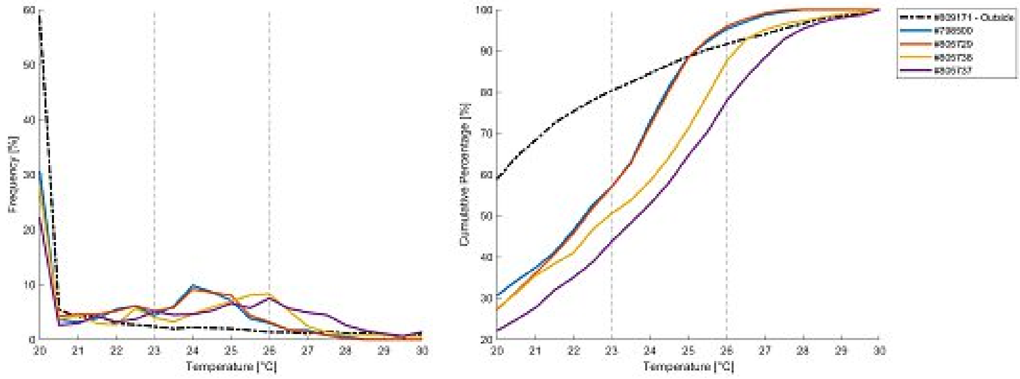


Figure 36: Temperature profile for the whole study period of KLG Hagedorn, House 1: temperature bins (left), cumulative temperature distribution (right)

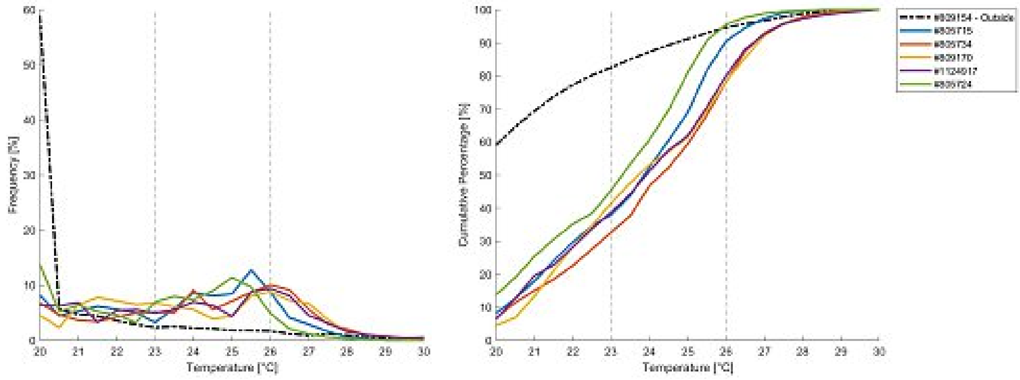


Figure 37: Temperature profile for the whole study period of KLG Hagedorn, House 2: temperature bins (left), cumulative temperature distribution (right)

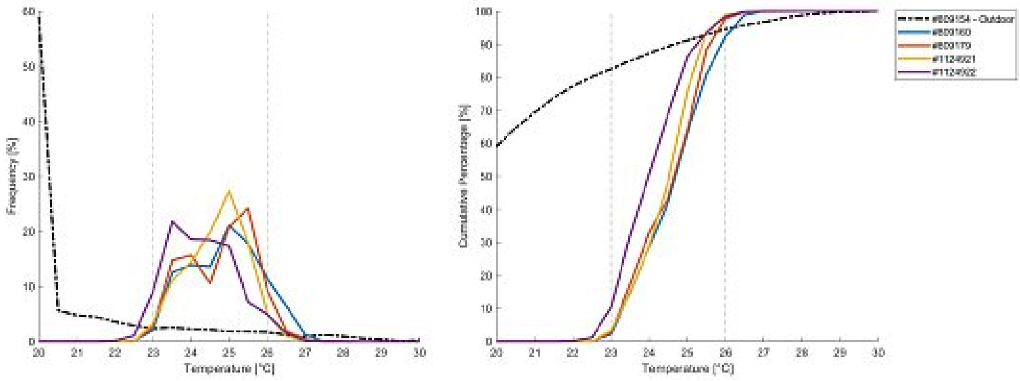


Figure 38: Temperature profile for the whole study period of KLG Hagedorn, House 3: temperature bins (left), cumulative temperature distribution (right)

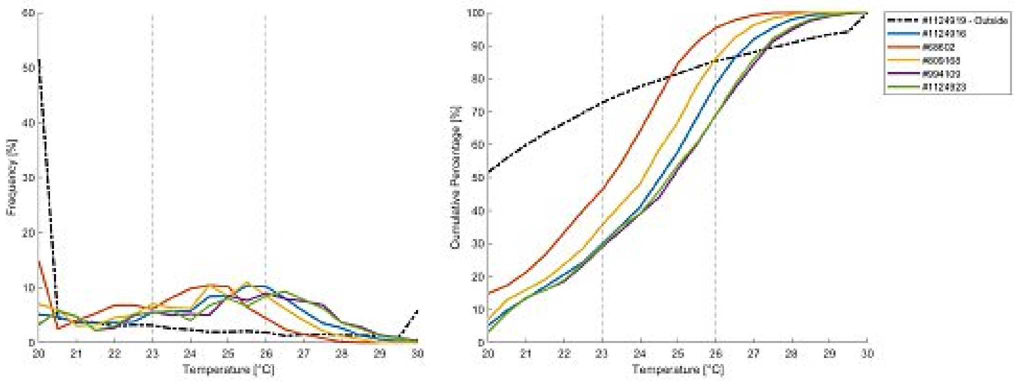


Figure 39: Temperature profile for the whole study period of KLG Eschenkogel: temperature bins (left), cumulative temperature distribution (right)

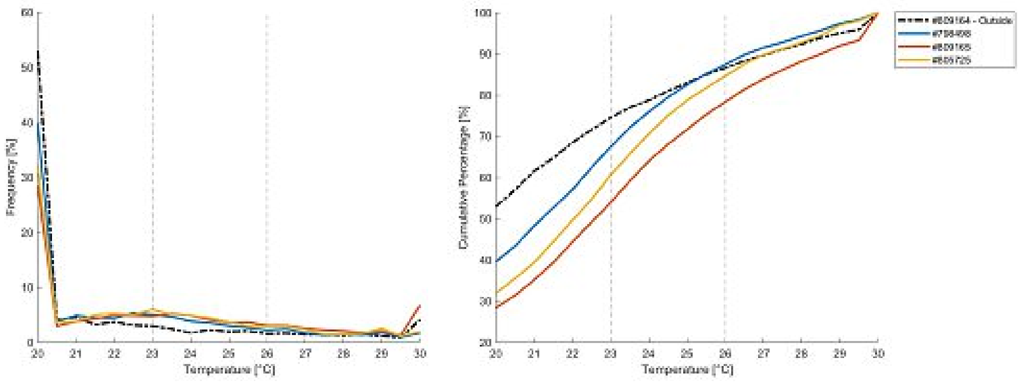


Figure 40: Temperature profile for the whole study period of the temporary KLG Klagergrube: temperature bins (left), cumulative temperature distribution (right)

Overall, the figures of three of the four allotment garden dwellings for year-round living, including *KLG Hagedorn House 2*, *House 3* and *KLG Eschenkogel*, show temperature peaks in the targeted range between 23 to 26°C. Especially at the temperature profile of *KLG Hagedorn House 3* 90% of the values are within the range (Figure 38). Only the ELKW allotment of *KLG Hagedorn House 1* shows high frequencies in lower temperatures. This allotment is the only one of the class ELKW which is not used as a primary residence and was therefore never heated during the study period, even though the outside temperature was often to be found lower than 20°C.

The *temporary KLG Klagergrube* shows a more distributed range of temperatures. The frequency of the temperature bins in Figure 40 shows a value of 5% with only a small peak at 23°C. The line plot for the cumulative percentage shows only a slow rise following the plot for the outside temperature. This is a result of a lack of insulation and opened door during the whole day. The inner temperatures therefore resemble the ones of the outdoor temperature with high temperatures during the day and lower temperatures during night.

4.2.1.2 Monthly Temperature - Living Rooms

Figure 41 to Figure 43 illustrate the monthly temperature values for the living rooms. As each month is part of the cooling season, the boundaries were again chosen as 23 and 26°C according to the standard. Further, each house is displayed in one colour: *KLG Hagedorn House 1* in blue, *KLG Hagedorn House 2* in orange, *KLG Hagedorn House 3* in yellow, *KLG Eschenkogel* in violet and the *temporary KLG Klagergrube* in green. The outside temperature, which was picked from the measured outside data of *KLG Hagedorn House 2*, is portrayed as a black broken-dotted line.

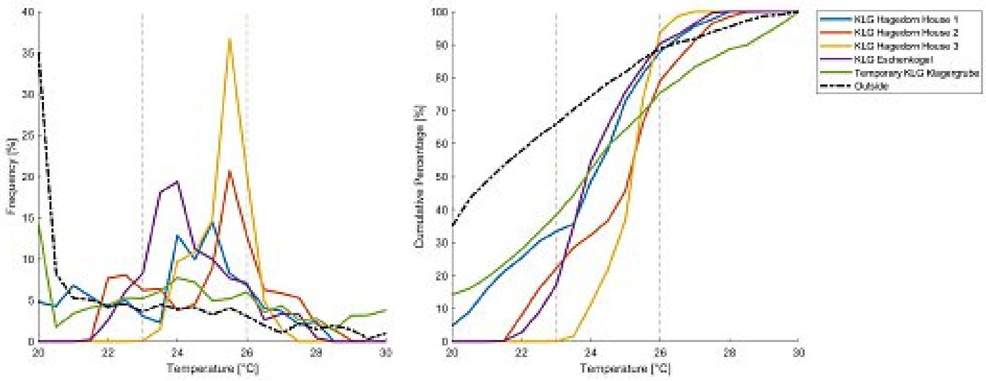


Figure 41: Living room temperatures in July: temperature bins (left), cumulative temperature distribution (right)

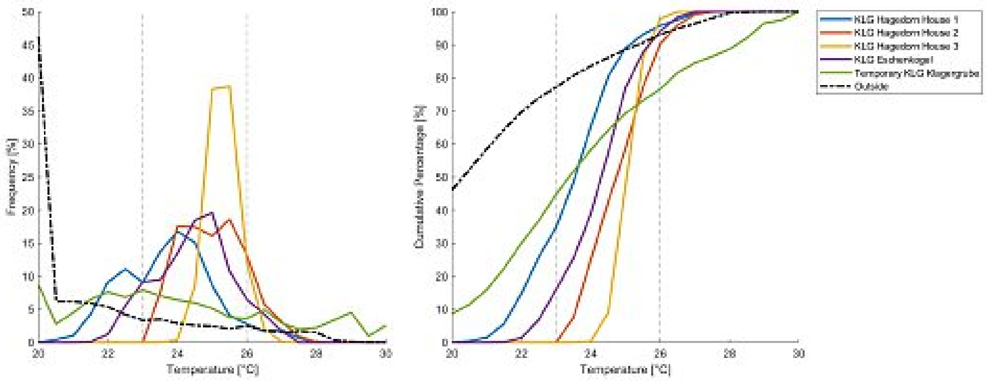


Figure 42: Living room temperatures in August: temperature bins (left), cumulative temperature distribution (right)

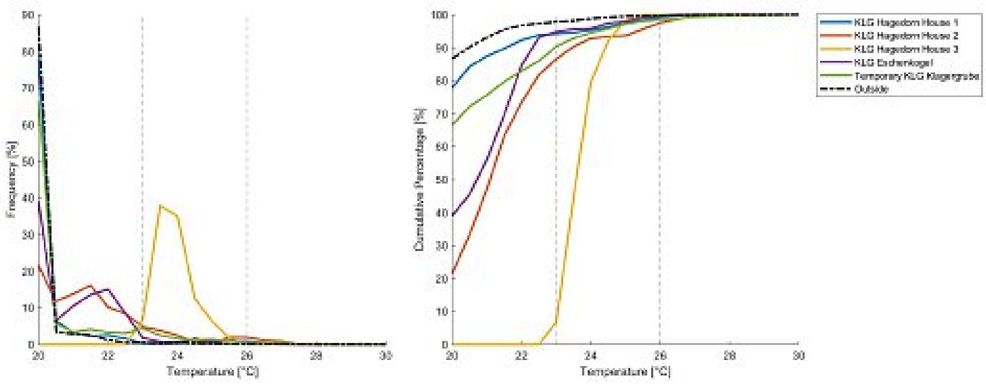


Figure 43: Living room temperatures in September: temperature bins (left), cumulative temperature distribution (right)

In July and August most values of the four EKLW are within the range of 23 to 26°C, showing only slight tendencies to one of the two boundaries. The temperature range from *KLG Hagedorn House 1* shows rather lower temperatures with an increase between 22 and 25°C in August. *KLG Hagedorn House 2* shows the same increase at slightly higher temperatures of 23 to 27°C. Especially KLG *Hagedorn House 3* has a high amount of nearly 40% of measured temperature values at around 25°C. In September, only *KLG Hagedorn House 3* displays most values inside the boundaries. *KLG Hagedorn House 3* is the newest building built with exterior walls of Porotherm and exterior insulation. The other houses built with less or no insulation, especially the *temporary KLG Klagergube*, show higher frequencies at lower temperatures, between 20 and 23°C. Again, the *temporary KLG Klagergrube* shows a similar lineplot to the outside temperature in all three months.

4.2.1.3 Monthly Temperature – Bedrooms 1

For the following figures the same boundaries were set as grey dashed lines. Further, the monthly temperature of the category ‘*Bedrooms 1’* is displayed in the same colour categories as in 4.2.1.1., representing the data of all main bedrooms of the four EKLW allotment garden dwellings. Again, the outside temperature is portrayed as a black broken-dotted line.

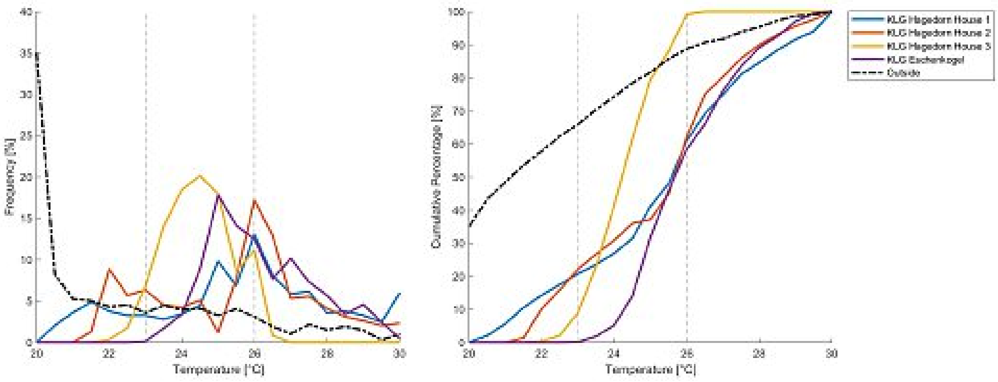


Figure 44: Bedroom 1 temperatures in July: temperature bins (left), cumulative temperature distribution (right)

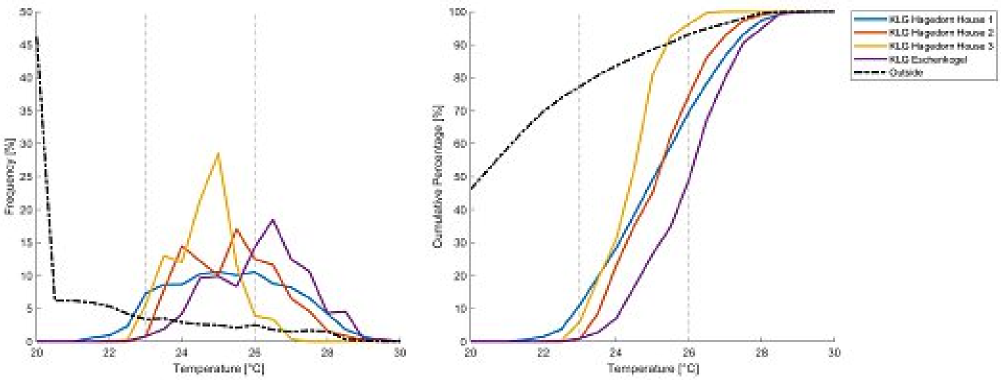


Figure 45: Bedroom 1 temperatures in August: temperature bins (left), cumulative temperature distribution (right)

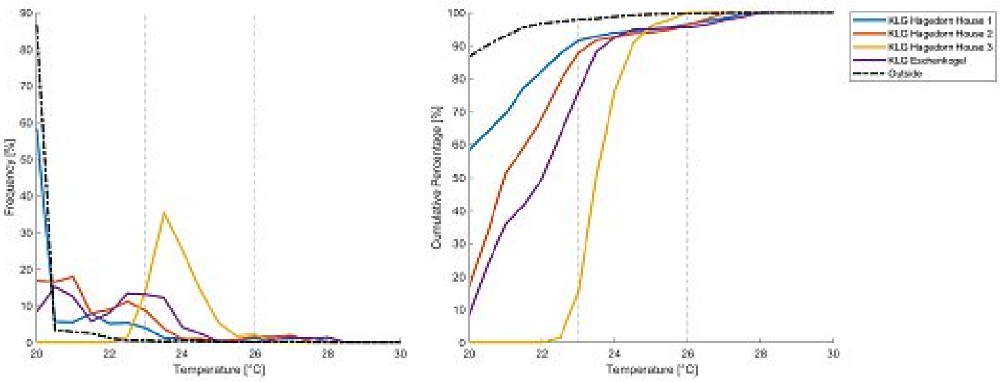


Figure 46: Bedroom 1 temperatures in September: temperature bins (left), cumulative temperature distribution (right)

Similar to the outcome of the living rooms, *KLG Hagedorn House 3* shows around 90% of values during all three months of the study period within the given range. As the *KLG Hagdorn House 3* Bedroom 1 is air conditioned it was possible for the occupants to adjust it to their liking both within cooling and heating. Bedroom 1 of *KLG Eschenkogel* shows higher frequencies of higher temperatures between 25 and 27°C in July and August. During September *KLG Hagedorn House 1* shows frequencies of 60% at 20°C as seen in Figure 46 which is a result of a tilted window during the whole night and day during the study period. As it is not used as a primary residence it was only used partly on rare occasions during daytime and is therefore always ventilated, but never heated. Overall, all Bedrooms 1 tend to show lower inside temperatures during September similar to the decreasing outside temperatures.

4.2.1.4 Monthly Temperature – Bedrooms 2

The graphs of Figure 47 to Figure 49 show the temperature bins and cumulative temperature distribution of the category '*Bedrooms 2*' for the four EKLW allotment garden dwellings. The outside temperature is portrayed as a black broken-dotted line. The colour range was picked similar to the chapters before: *KLG Hagedorn House 1* in blue, *KLG Hagedorn House 2* in orange, *KLG Hagedorn House 3* in yellow and *KLG Eschenkogel* in violet. Further, the dashed boundaries were again picked to be 23 and 26°C.

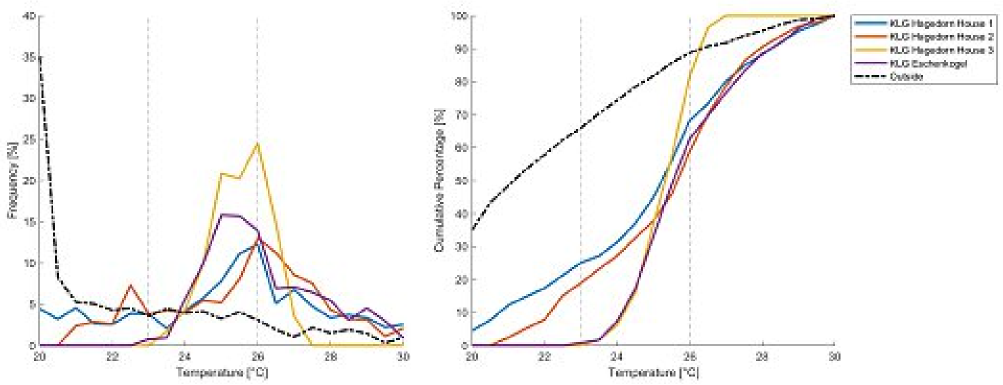


Figure 47: Bedroom 2 temperatures in July: temperature bins (left), cumulative temperature distribution (right)

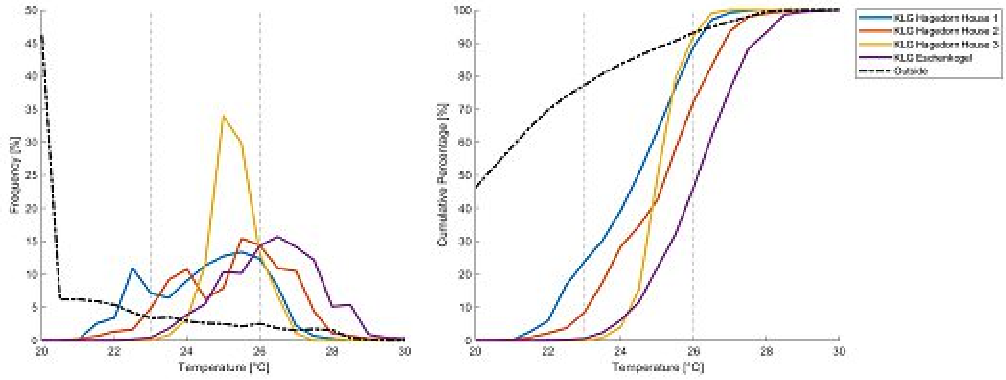


Figure 48: Bedroom 2 temperatures in August: temperature bins (left), cumulative temperature distribution (right)

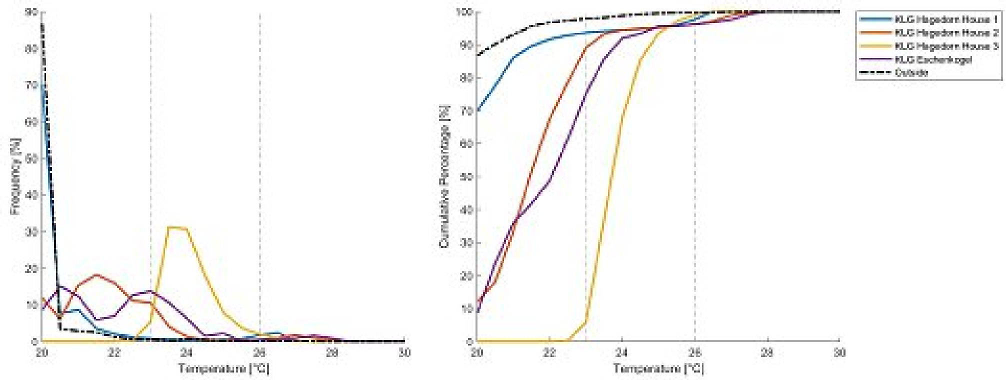


Figure 49: Bedroom 2 temperatures in September: temperature bins (left), cumulative temperature distribution (right)

Overall, the bedrooms under category '*Bedrooms 2*' show quite similar results to the ones in category '*Bedroom 1*'. Especially Bedroom 1 and Bedroom 2 of the *KLG Eschenkogel* show similar results as they are facing the same direction and are about the same size.

As seen in Figure 47 in July the Bedrooms 2 of *KLG Eschenkogel* and *KLG Hagedorn House 3* show an increase of the cumulative percentage inside the two boundaries. The frequency of the *KLG Eschenkogel* temperature peaks at 25°C, whereas the KLG Hagedorn House 3 peaks at 26°C.

In August the temperature values can be found around the higher temperature boundary of 26°C. Similar to the category of '*Bedrooms 1*' the *KLG Hagedorn House 1* Bedroom 2 shows high frequencies of nearly 70% during lower temperatures of ≤ 20°C. Again, this is a result of the consistently tilted window, ventilating the small room constantly during the whole study period. Accordingly, the temperature aligns with the outside temperature, especially at colder temperatures. Only *KLG Hagedorn House 3* shows most values within the boundaries (Figure 49).

4.2.2 Relative Humidity

The following figures show the relative humidity bins and the cumulative relative humidity distribution for each allotment garden for the whole study period and for each room category in each month. The boundary limits were chosen to be 20 and 80%, similar to the ones in the ASHRAE Standard 55 as they are perceived as comfortable. These boundaries are illustrated as dashed grey lines. As within 40 to 60% the conditions are optimal to minimize risks to human health (Sterling, Arundel, Sterling, 1985), these boundaries were illustrated as dotted grey lines.

4.2.1.5 Relative Humidity profile of each allotment

The relative humidity profiles of all loggers of each allotment garden dwelling are illustrated in Figure 50 to Figure 54. Further, each monitored outside relative humidity is included. The outside humidity is portrayed as a black broken-dotted line. The middle part between the grey dotted boundaries is perceived as comfortable by most people and has optimal conditions for a minimization of health risks.

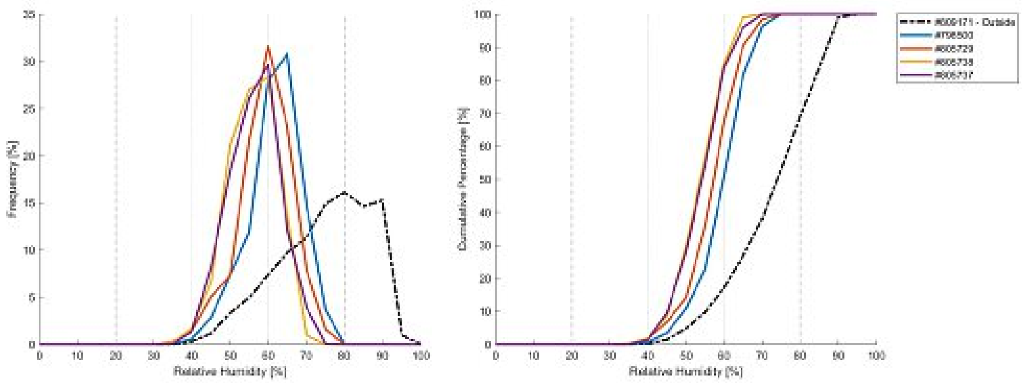


Figure 50: Relative humidity profile for the whole study period of KLG Hagedorn, House 1: relative humidity bins (left), cumulative relative humidity distribution (right)

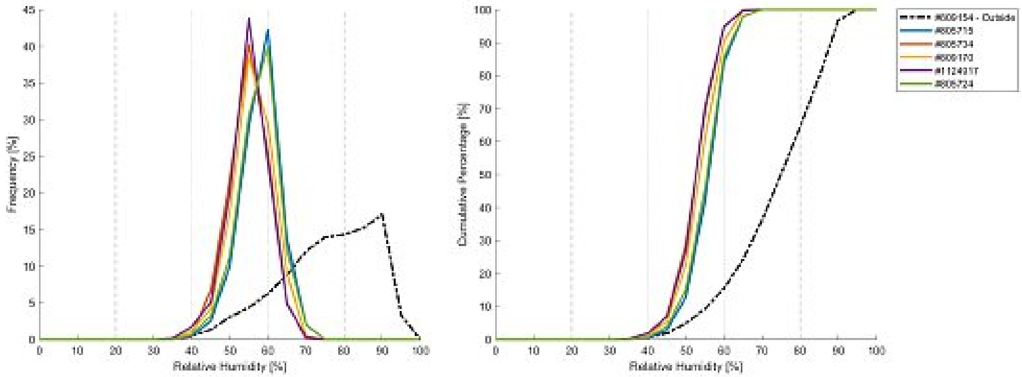


Figure 51: Relative humidity profile for the whole study period of KLG Hagedorn, House 2: relative humidity bins (left), cumulative relative humidity distribution (right)

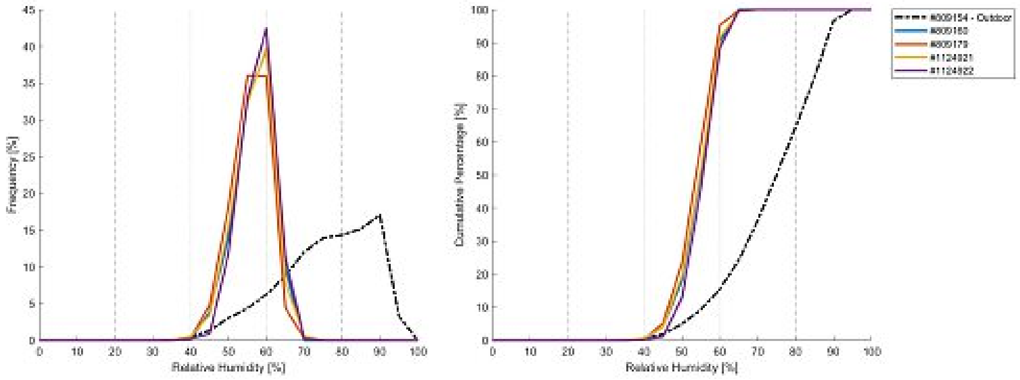


Figure 52: Relative humidity profile for the whole study period of KLG Hagedorn, House 3: relative humidity bins (left), cumulative relative humidity distribution (right)

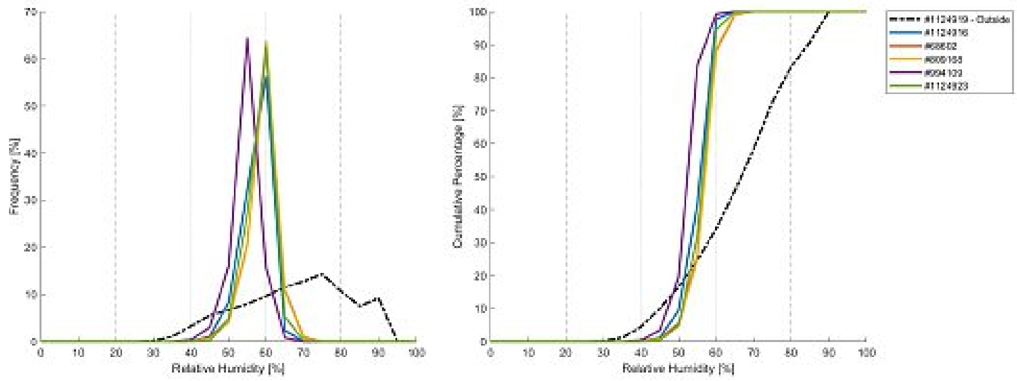


Figure 53: Relative humidity profile for the whole study period of KLG Eschenkogel: relative humidity bins (left), cumulative relative humidity distribution (right)

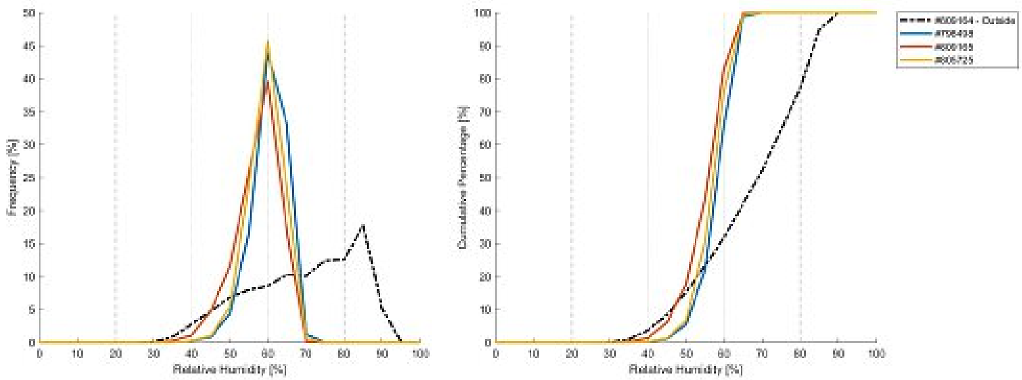


Figure 54: Relative humidity profile for the whole study period of the temporary KLG Klagergrube: relative humidity bins (left), cumulative relative humidity distribution (right)

The relative humidity values for all data loggers at *KLG Hagedorn House 1* peak at around 60%. All of the measured interior values are within the comfortable range between 20 and 80%. Further, the rise within the cumulative percentage is illustrated especially within the range from 40 to 70%. *KLG Hagedorn House 2* shows a similar behaviour at a lower relative humidity range from 40 to 65%. Even though *KLG Hagedorn House 3* is the newest building, the relative humidity frequencies are quite similar to the ones of *KLG Hagedorn House 2*. At *KLG Eschenkogel* the relative humidity peaks at a frequency of around 65% at 50% RH and 65% at 60% RH. As a result, the relative humidity can be found within the comfortable range and on the edge of minimization of health risks most of the time. The *temporary KLG Klagergube* also shows peaks at 60% relative humidity with a rise of the cumulative percentage between 40 to 70% relative humidity. Overall, all five houses show results within the relative humidity comfort range of 20 to 80%. The three houses which are used for living during the whole period: *KLG Hagedorn House 2, KLG Hagedorn House 3* and *KLG Eschenkogel* show slightly better results within the minimization of health risk range between 40 to 60% as they are ventilated in a controlled way by the owners.

4.2.1.6 Monthly Relative Humidity – Living Rooms

Figure 55 to Figure 57 illustrate the monthly relative humidity bins and the cumulative relative humidity distribution for the living rooms. Each house is displayed in one colour: *KLG Hagedorn House 1* in blue, *KLG Hagedorn House 2* in orange, *KLG Hagedorn House 3* in yellow, *KLG Eschenkogel* in violet and the *temporary KLG Klagergrube* in green. The outside humidity is again portrayed as a black broken-dotted line and was used of the monitored outside data of *KLG Hagedorn House 2*. As the *temporary KLG Klagergube* only consists of one main room, this room is compared to the other living rooms. The limits for comfort and the minimization of health risks are illustrated as grey dashed and dotted lines.

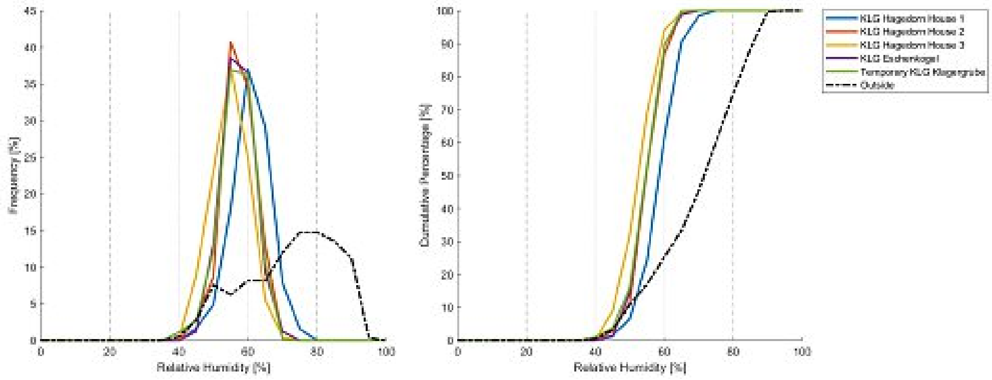


Figure 55: Living room relative humidity in July: relative humidity bins (left), cumulative relative humidity distribution (right)

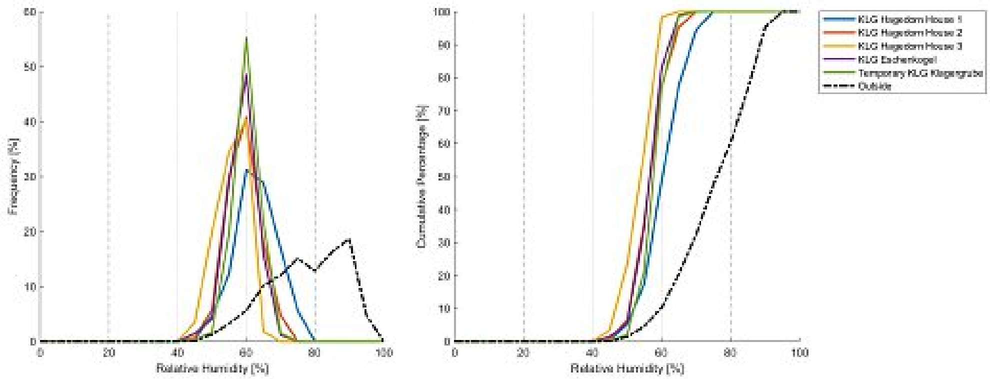


Figure 56: Living room relative humidity in August: relative humidity bins (left), cumulative relative humidity distribution (right)

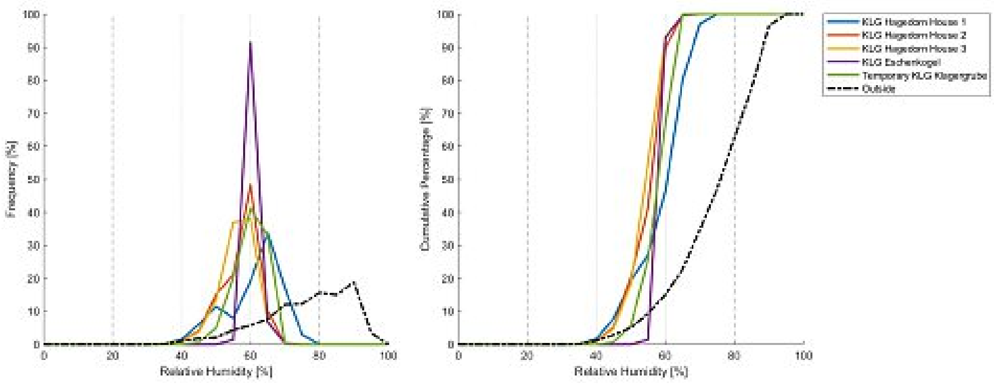


Figure 57: Living room relative humidity in September: relative humidity bins (left), cumulative relative humidity distribution (right)

During July all living rooms except for *KLG Hagedorn House 1* peak within the minimization of health risk range, whereas *KLG Hagedorn House 1* peaks at the edge of 60%. As the study period proceeds, the peaks of frequencies shift to higher relative humidity values of 60% in August and 60 to 70% in September. Similar to chapter 4.2.1.5 the relative humidity values peak at a frequency of 60% in all three months, staying within the comfort range according to the standard. Overall, the living room of *KLG Hagedorn House 1* shows a tendency to higher relative humidity values than the other allotments, which can be explained by the low ventilation rates of the living room as it is only used part time. Further, it is possible, that the exterior walls are containing a higher moisture content than the other allotments.

4.2.1.7 Monthly Relative Humidity – Bedrooms 1

The following figures illustrate the monitored relative humidity values for each Bedroom 1 of the four EKLW allotment garden dwellings during each month of the study period. The colour schemes are applied according to their house colour.

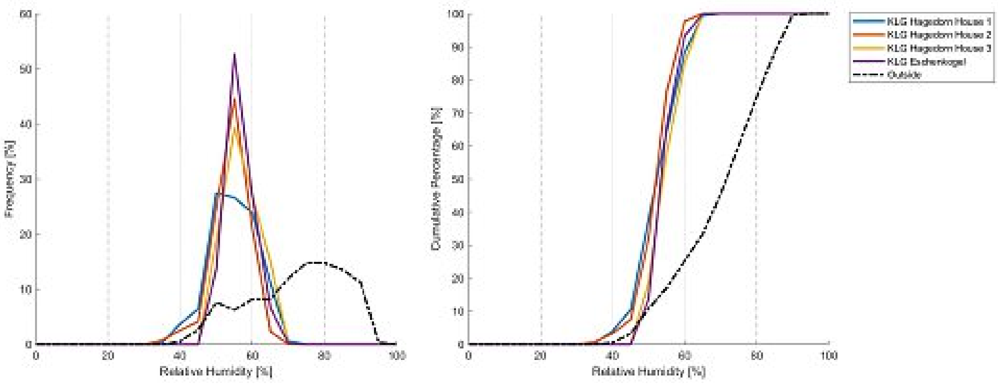


Figure 58: Bedroom 1 relative humidity in July: relative humidity bins (left), cumulative relative humidity distribution (right)

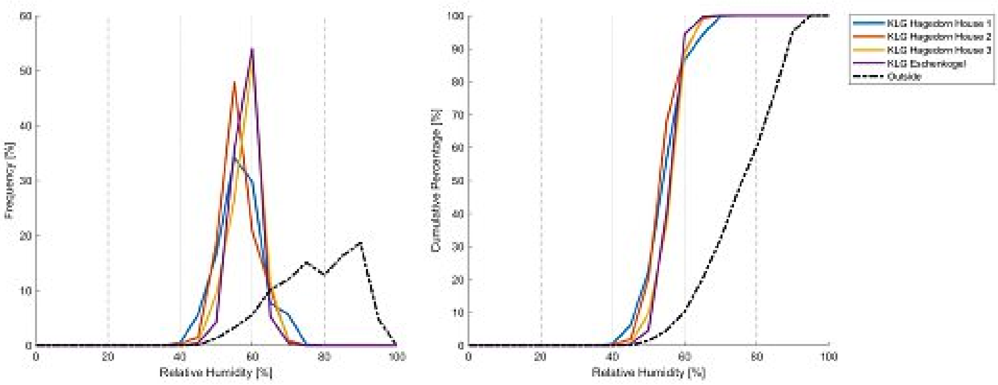


Figure 59: Bedroom 1 relative humidity in August: relative humidity bins (left), cumulative relative humidity distribution (right)

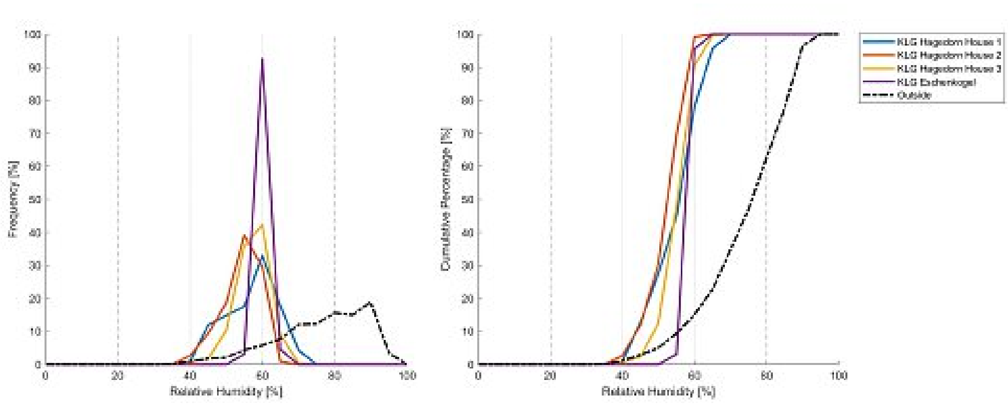


Figure 60: Bedroom 1 relative humidity in September: relative humidity bins (left), cumulative relative humidity distribution (right)

As Bedroom 1 is always ventilated during July and August at *KLG Hagedorn House 1*, this category performs slightly better than the values of the living room. As seen in Figure 58 to Figure 60 the relative humidity always lies within the comfort range and mostly stays within the minimization of health risks range also. The other allotments for EKLW show similar results. Especially Bedroom 1 of *KLG Eschenkogel* shows high frequencies of 50% at around 50% RH in July and 50% and around 60% RH in August and September. The better humidity performance can be explained by the wooden construction of the overall house. All three allotments of *KLG Hagedorn*, which were built as brick constructions, show a wider range of relative humidity values in September. They are still performing within both ranges.

4.2.1.8 Monthly Relative Humidity – Bedrooms 2

Figure 61 to Figure 63 show the relative humidity bins and cumulative relative humidity distribution for the category of '*Bedrooms 2*', which include the bedrooms and guest rooms of the four allotments for year-round living. Further, the graphs are categorized in July, August and September.

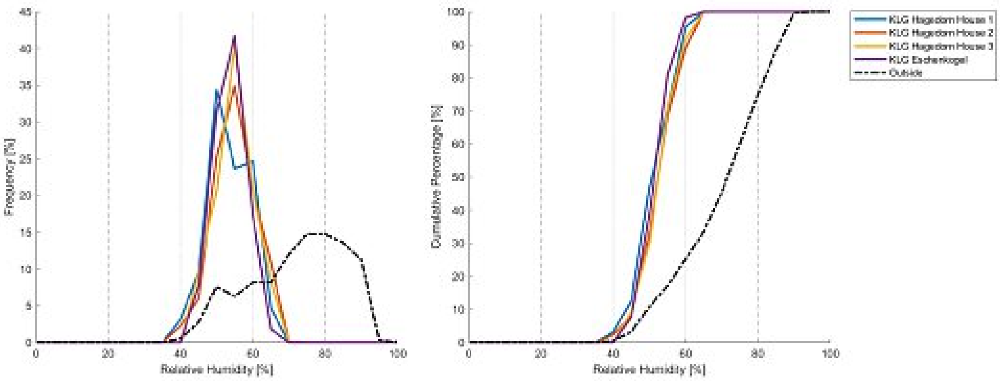


Figure 61: Bedroom 2 relative humidity in July: relative humidity bins (left), cumulative relative humidity distribution (right)

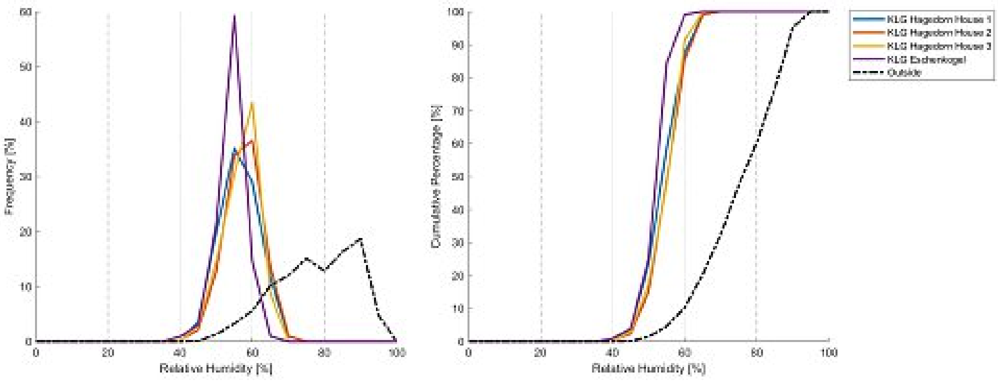


Figure 62: Bedroom 2 relative humidity in August: relative humidity bins (left), cumulative relative humidity distribution (right)

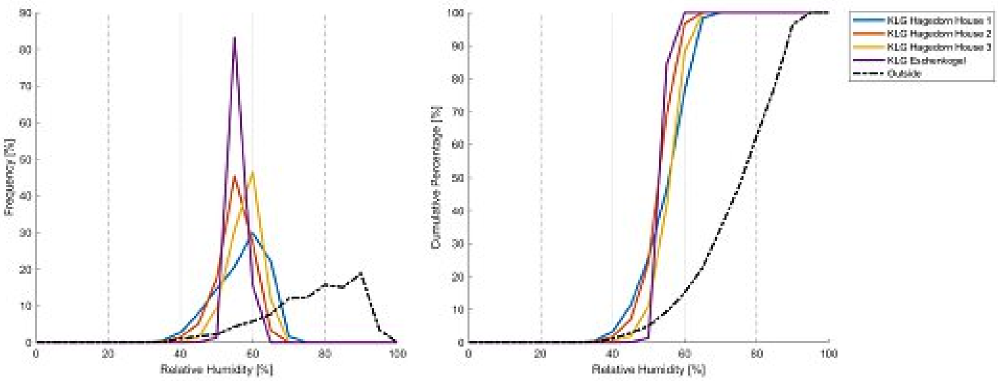


Figure 63: Bedroom 2 relative humidity in September: relative humidity bins (left), cumulative relative humidity distribution (right)

The category of '*Bedrooms 2*' performs quite similar to the category of '*Bedrooms 1*'. As Bedroom 2 at *KLG Hagedorn House 1* is also always ventilated by a tilted window during July and August it also performs better in terms of the minimization of health risk range than the living room. During July all four allotments show the highest increase between 40 to 60% relative humidity in the chart for the cumulative distribution (Figure 61). As the study period progresses, the peaks slightly shift to higher relative humidity values, but still performing good within both ranges. Again, this can be explained by a reduced ventilation rates during colder days in September described by the owners.

4.3 Thermal Neutrality

The following figures show the calculated Neutrality Temperature T_n as well as the ranges of T_n +2.5 to T_n -2.5 °C. Within this chosen range 90% of people accept the inside temperatures (Szokolay, 2014). Accordingly, the following graphs show the correlation of these calculated ranges from the monitored outside temperatures to the monitored inside temperature course. Further, the percentage of monitored temperatures inside this range is illustrated. Each inside temperature line plot shows the colour allocated to its allotment garden house: *KLG Hagedorn House 1* in blue, *KLG Hagedorn House 2* in orange, *KLG Hagedorn House 3* in yellow, *KLG Eschenkogel* in violet and the *temporary KLG Klagergrube* in green. The outside temperature of each allotment garden dwelling is illustrated in black.

4.3.1 Monthly Neutrality - Living Rooms

The living rooms are often perceived as the main rooms of a house, as they are the rooms which are used by all family members. The graphs Figure 64 to Figure 66 compare the neutrality temperature range to the line plot of the measured inside temperature of the living rooms of each allotment garden dwelling.

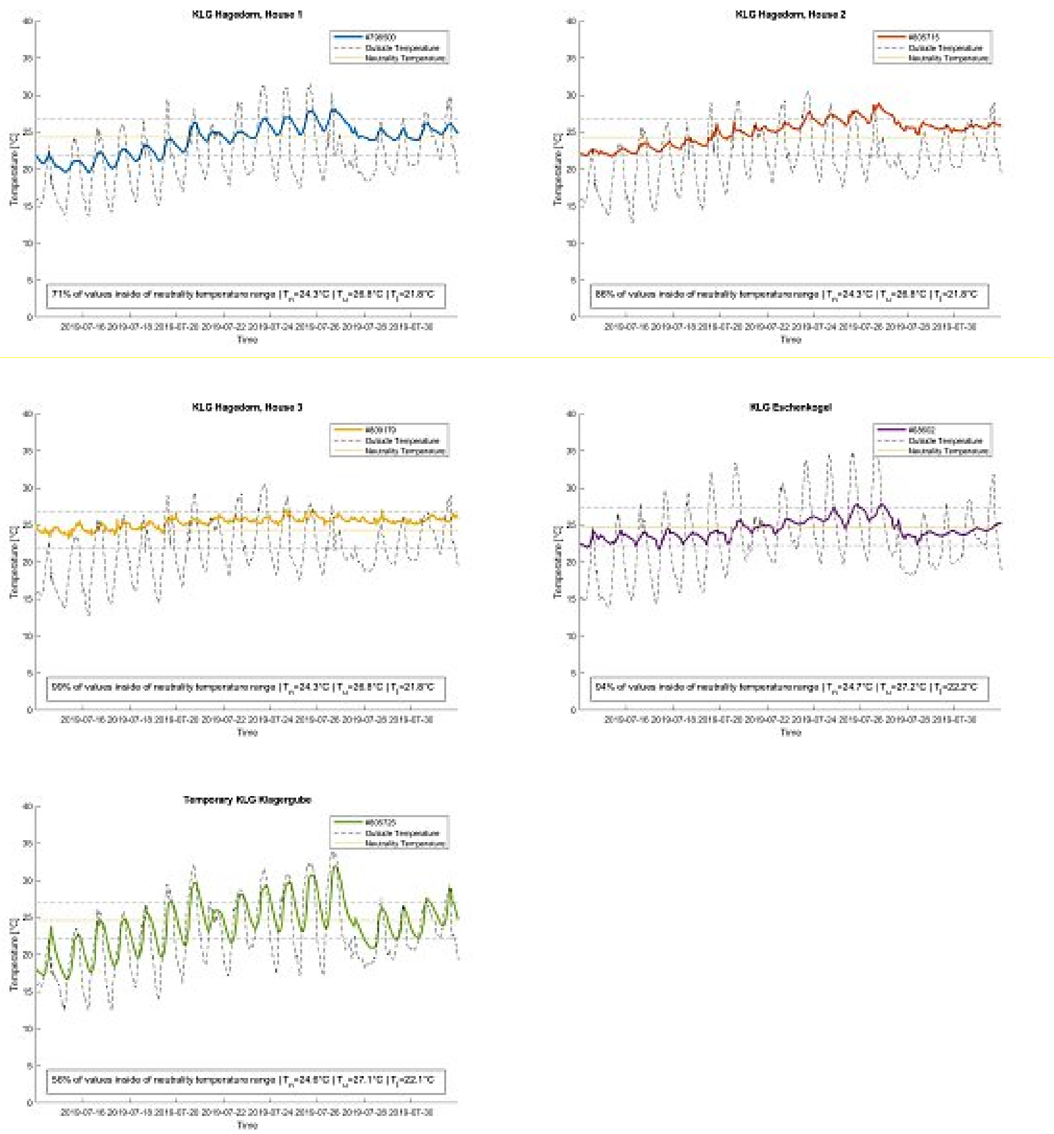


Figure 64: Thermal Neutrality ranges of July – Living rooms

Even though July was the hottest month of the study period it started with quite low temperatures around 17°C. Still, all living rooms exceed 50% of values inside the neutrality range during July. Especially by comparing *KLG Hagedorn House 3* and the *temporary KLG Klagergrube*, it is visible, that the newest and well insulated *KLG Hagedorn House 3*, which is used for year-round living performs way better than the fluctuating temperature of the *temporary KLG Klagergrube* which resembles the flow of the outside temperature. This can be explained by the lack of insulation and opened window and door during the whole daytime. Therefore, the inside temperature increased simultaneously to the outside temperature, but would not reduce as much during night when the window and door are both closed.

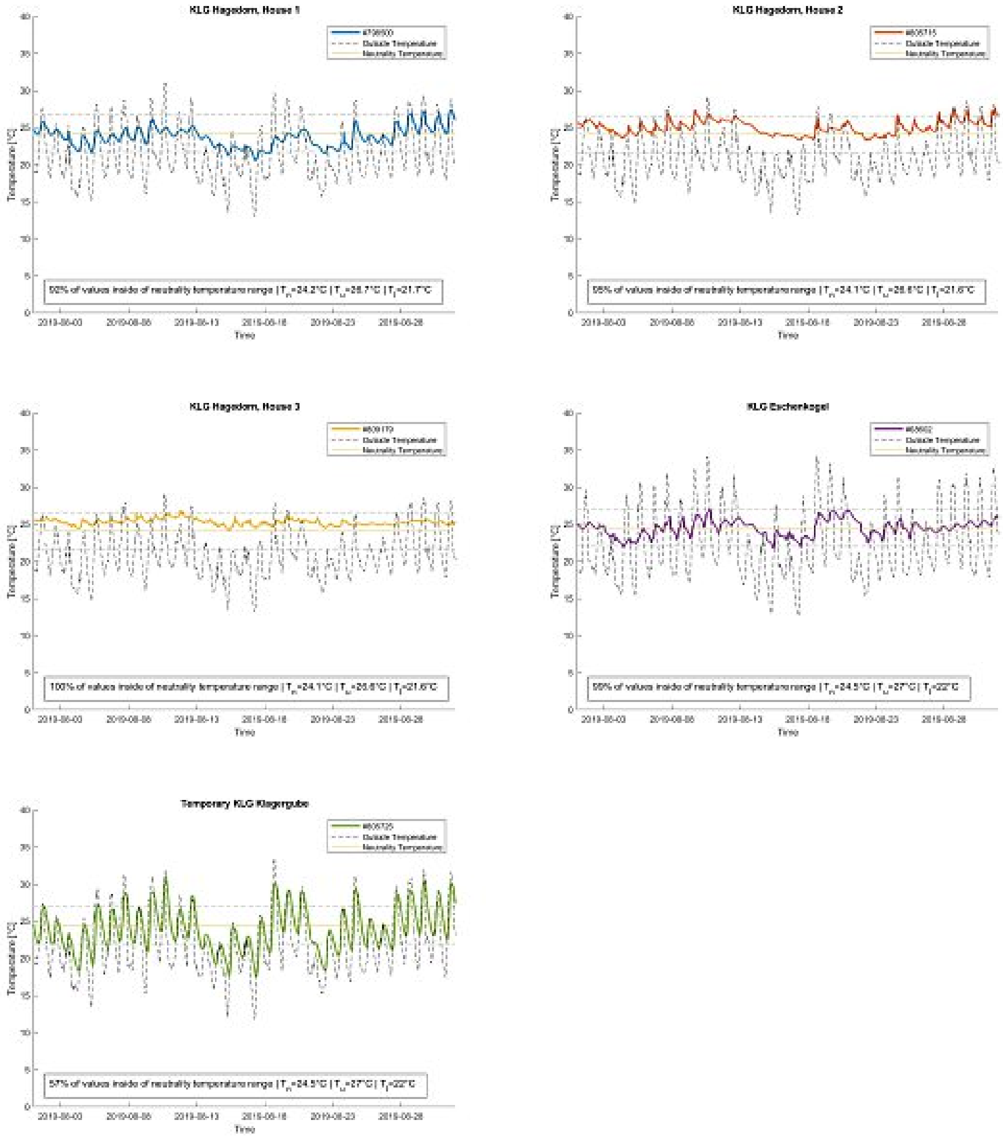


Figure 65: Thermal Neutrality ranges of August – Living rooms

The month of August shows the best results for all living rooms. The highest percentage of 100%, which is displayed in Figure 65, is shown by *KLG Hagedorn House 3*, whereas the lowest value of 57% is shown by the *temporary KLG Klagergrube*. Again, the line plot for the inner temperature of the *temporary KLG Klagergrube* shows a similar flow to the outside temperatures, especially during the warmer day times.

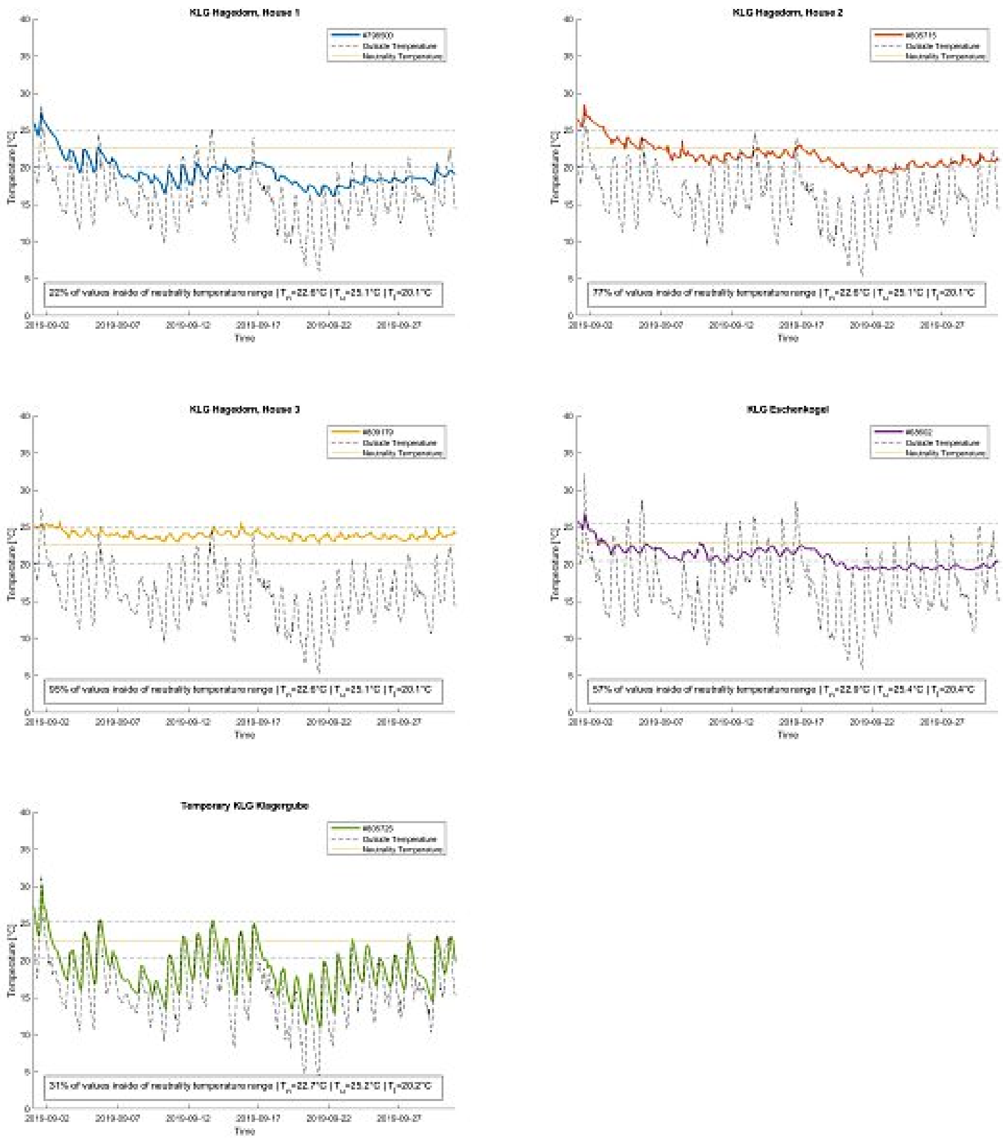


Figure 66: Thermal Neutrality ranges of September – Living rooms

Major fluctuations for the inside temperature within the main room of the *temporary KLG Klagergrube* are visible again during September. Therefore, the fluctuation exceeds the neutrality range, which can be especially seen in Figure 66. The *temporary KLG Klagergrube* obtains low percentage rates during all three monitored months as it is the only one not insulated and only ventilated during daytime. On the other hand, the temperature of the living room in *KLG Hagedorn House 3* stays rather constant inside the range for the whole study period with the highest percentages inside the neutrality range during all three months.

The temperature shift from warmer to cooler temperatures and therefore a shift in the percentages inside the range of the allotment garden dwellings is visible for all houses. The uninhabited *KLG Hagedorn House 1* and the *temporary KLG Eschenkogel* are most outstanding within this shift, which is further displayed in the following table:

Table 2: Percentage inside of the Neutrality Temperature range – Bedrooms 3

	July	August	September
KLG Hagedorn House 1	71%	92%	22%
KLG Hagedorn House 2	86%	95%	77%
KLG Hagedorn House 3	99%	100%	95%
KLG Eschenkogel	94%	99%	57%
Temporary KLG Klagergrube	56%	57%	31%

Especially for the living room of the *KLG Hagedorn House 1*, the percentage inside the neutrality range started in July with 71%, with a peak of 92% in August and a rather low value of 22% in September. At *KLG Hagedorn House 3* the percentages of the living room differ only by 5%. Therefore, at most temperatures 90% of people would view the temperature as neutral. The same trend is visible for the living room of *KLG Eschenkogel* during July and August, whereas the percentage drastically decreased to 57% in September. This can be explained by the lower insulation and lower storage mass of the timber frame construction in contrast to the massive brick constructions of the three allotments of *KLG Hagedorn*.

4.4 Psychrometric Analysis

In Figure 67 to Figure 75 the relationship of the measured temperature and relative humidity as well as their comfort ranges are illustrated in psychrometric charts. The comfort zones were created as described in 3.6.2.2, with side boundaries of the neutrality temperature range for each month and each allotment garden separately. The lower and upper boundary for the relative humidity curves were taken as 20% and 80% as stated in the ASHRAE Standard 55 (2017). These comfort boundaries are illustrated as the comfort window in red in each psychrometric chart.

Similar to the chapters before, each measured point is described in different colours according to each allotment garden dwelling. The *KLG Hagedorn House 1* is illustrated in blue, the *KLG Hagedorn House 2* in orange, the *KLG Hagedorn House 3* in yellow, the *KLG Eschenkogel* in violet and the *temporary KLG Klagergrube* in green.

The following figures are divided into living rooms and the two types of bedrooms. As the *temporary KLG Klagergube* only consists of one room, this room is compared to the living rooms of the other allotments. Further each month of the study period is illustrated.

4.4.1 Monthly Psychrometric Analysis – Living rooms

The graphs Figure 67 to Figure 69 show the psychrometric charts for the living rooms analyzed for each month of the study period starting with July, then August, followed by September.

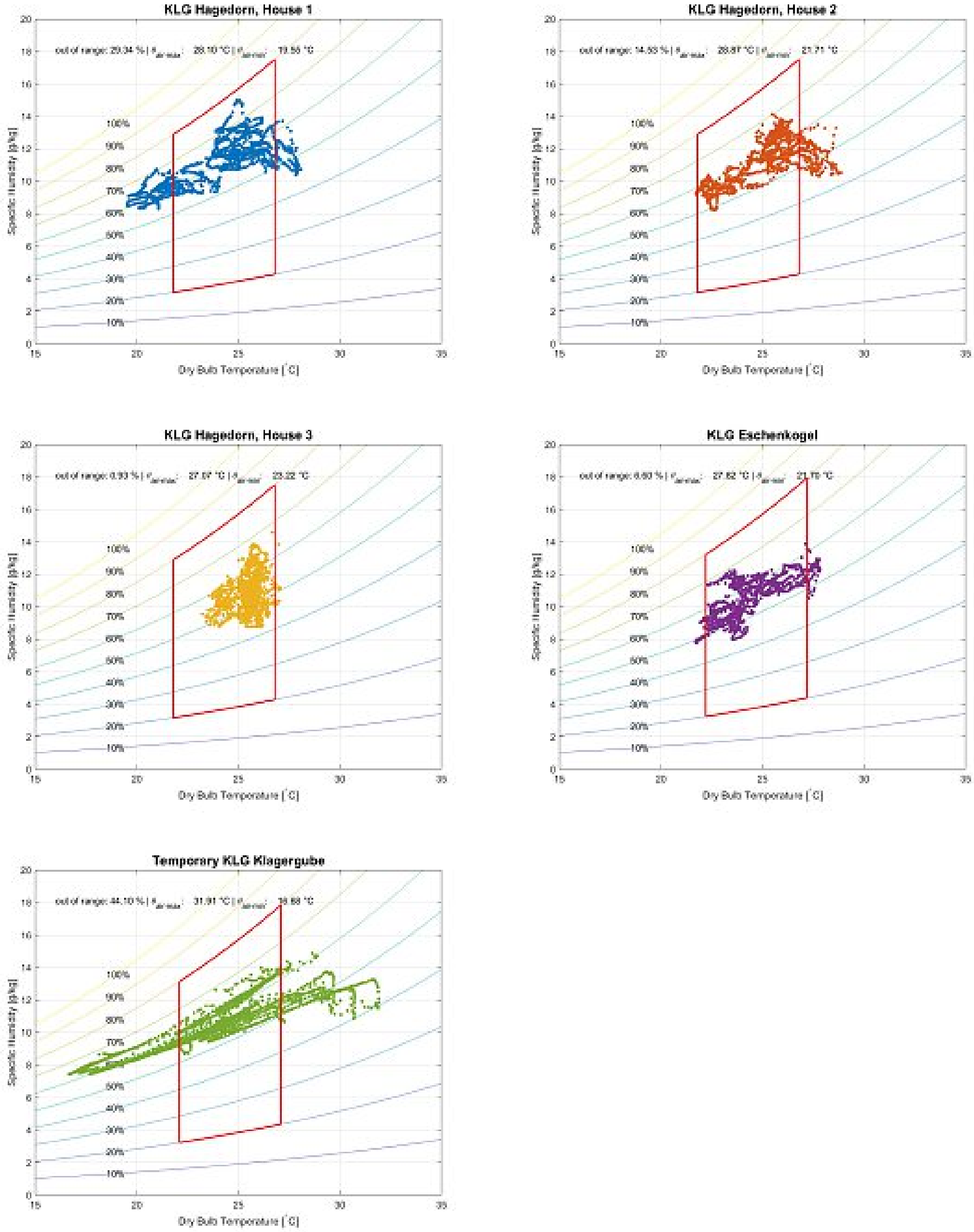


Figure 67: Psychrometric charts of July – Living rooms

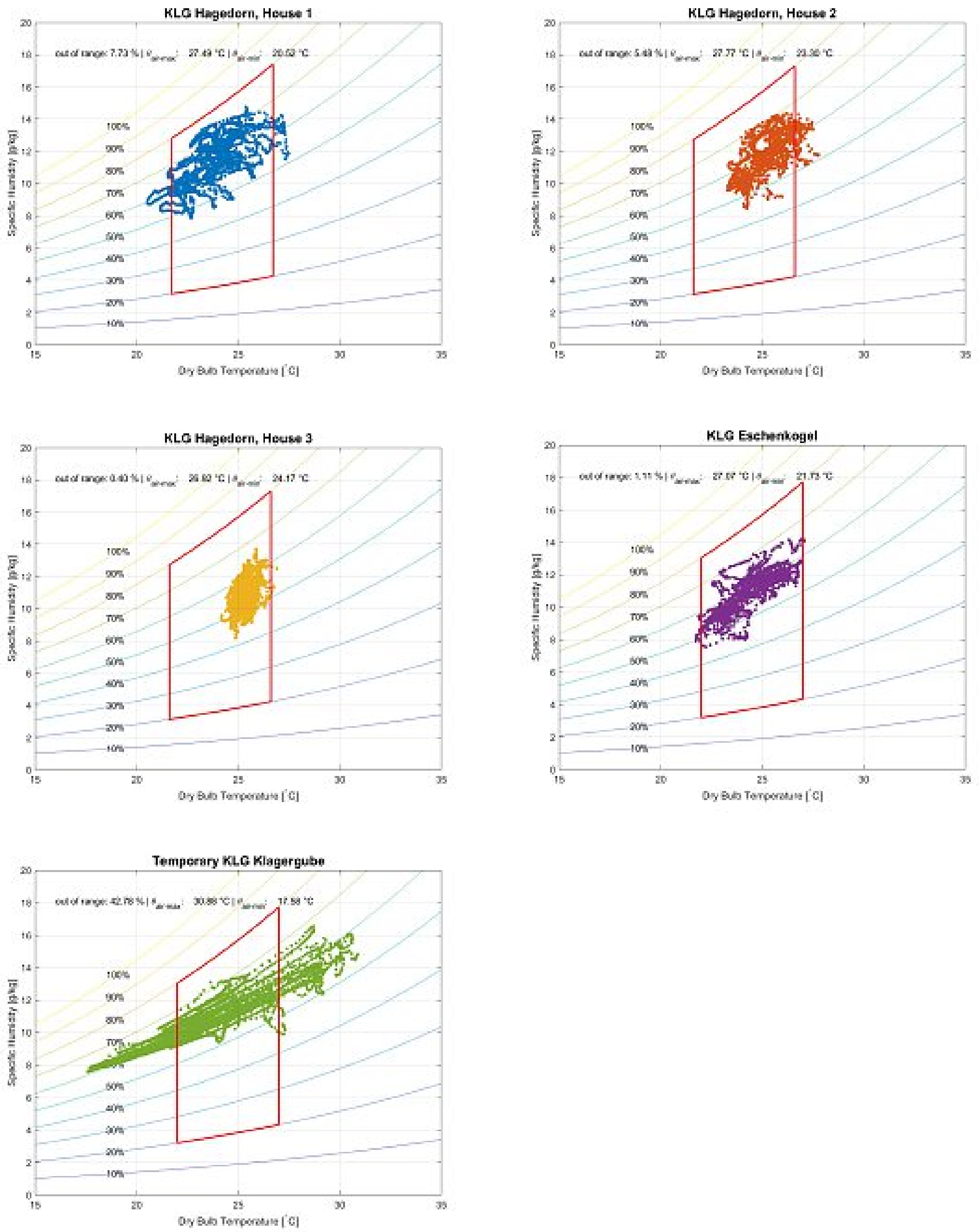


Figure 68: Psychrometric charts of August – Living rooms

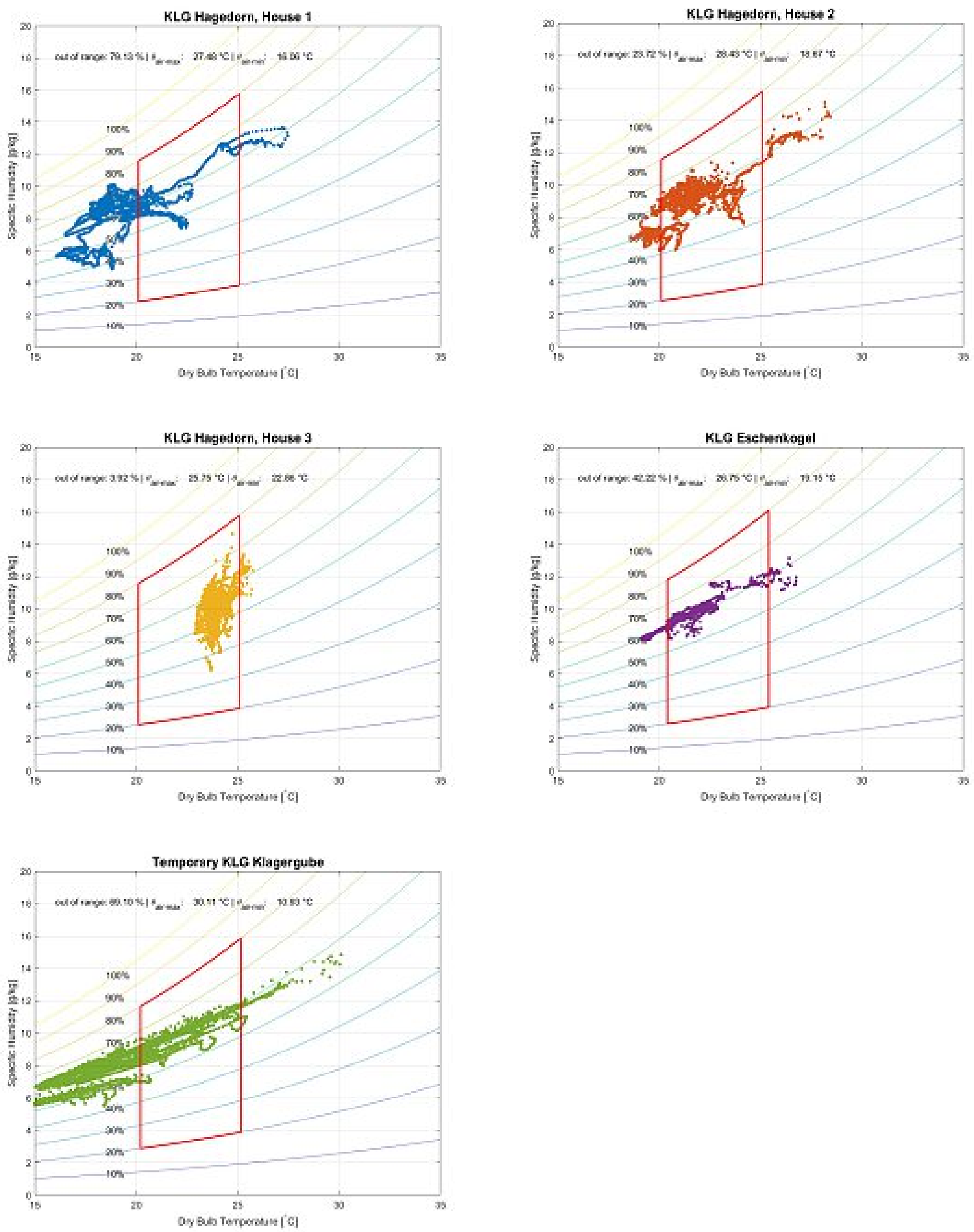


Figure 69: Psychrometric charts of September – Living rooms

Overall, the living room of the newest allotment *KLG Hagedorn House 3* performs superior during all three months. The temperature requirements of the ÖNORM EN 16798-1 of 23 to 26°C for cooling season and 20 to 25°C during heating season are quite similar to the ones of the side boundaries, which were calculated by the neutrality temperature ranges. For the other allotments, the numbers of points that meet the comfort criteria peak in August, whereas the percentage drops during lower temperatures at the beginning of July and throughout September as seen in Figure 67 and Figure 69. As *KLG Hagedorn House 1* is uninhabited and only used part time during the summer period it is rarely heated, especially during fall but ventilated many hours per day, when in usage. Therefore, the percentage of lower temperatures outside the boundary of Tmin rises from August to September by 71.2%.

Table 3: Percentage of points outside the comfort zone – Living rooms

	July	August	September
KLG Hagedorn House 1			
< Tmin	21.6%	5.1%	76.3%
> Tmax	7.7%	2.7%	2.9%
KLG Hagedorn House 2			
< Tmin	0.6%	0.2%	17.3%
> Tmax	14.0%	5.5%	6.5%
KLG Hagedorn House 3			
< Tmin	0.0%	0.2%	0.1%
> Tmax	0.9%	0.4%	3.9%
KLG Eschenkogel			
< Tmin	2.5%	0.9%	40.5%
> Tmax	4.3%	0.4%	1.9%
Temporary KLG Klagergrube			
< Tmin	26.3%	25.9%	66.1%
> Tmax	17.8%	17.0%	3.1%

Furthermore, the number of points under the temperature boundary Tmin peak for four of these five houses in September. As *KLG Hagedorn House 2* is used for year-round living and was already partly heated during fall, the <Tmin value of 17.3% is lower than the value of 76.3% of *KLG Hagedorn House 1*, which was built in similar materials during the same construction period. *KLG Hagedorn House 3* shows its highest percentage of points above the Tmax boundary with 3.9%.

Similar to the results of the neutrality temperature, the points for the *temporary KLG Klagergrube* show a rather big range from low to high temperatures as well as low and high absolute humidity values due to the lack of insulation at the allotment. As both values fluctuate through all three months, the number of points outside the comfort criteria is quite high compared to the other houses, which can be seen in Table 3 especially in July and August. Similar to the other allotments, the highest percentage of 66.1% can be found in September.

4.4.2 Monthly Psychrometric Analysis – Bedrooms 1

The following psychrometric charts show the results for the bedrooms analyzed for each month of the study period starting with July, then August and September. The bedrooms under category *'Bedrooms 1'* are the main bedrooms of each house which are primarily used as sleeping rooms. Bedroom 1 at *KLG Hagedorn House 3* is air conditioned during night.

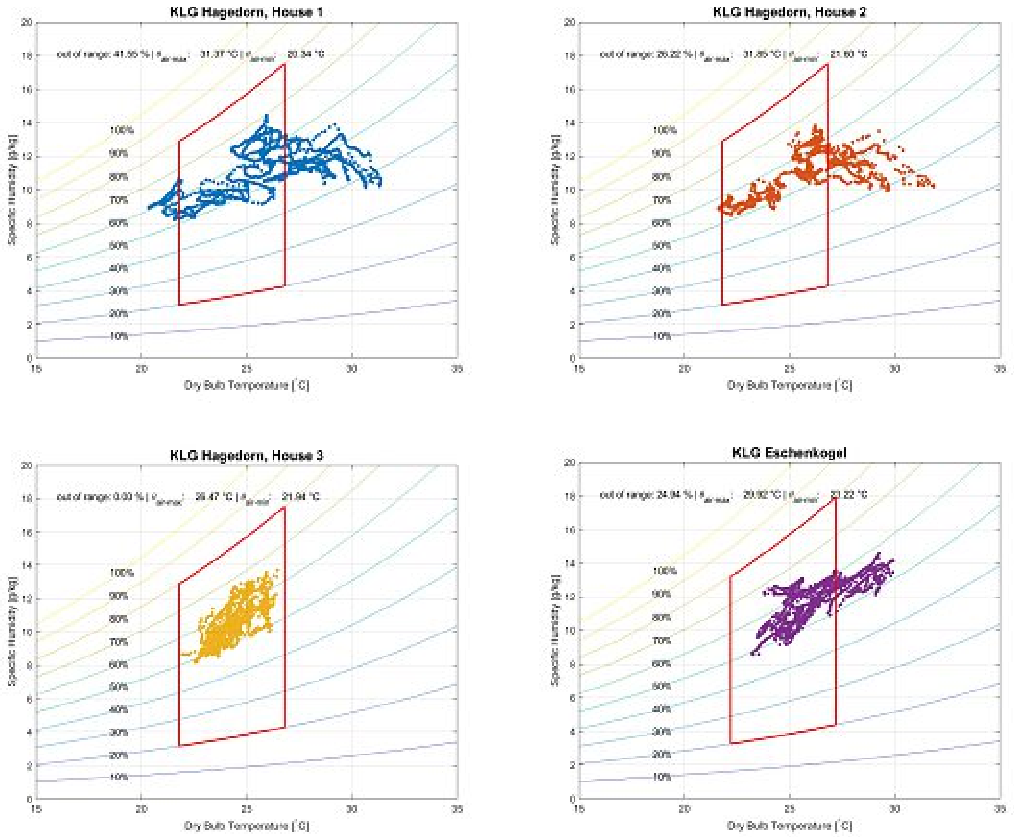


Figure 70: Psychrometric charts of July – Bedrooms 1

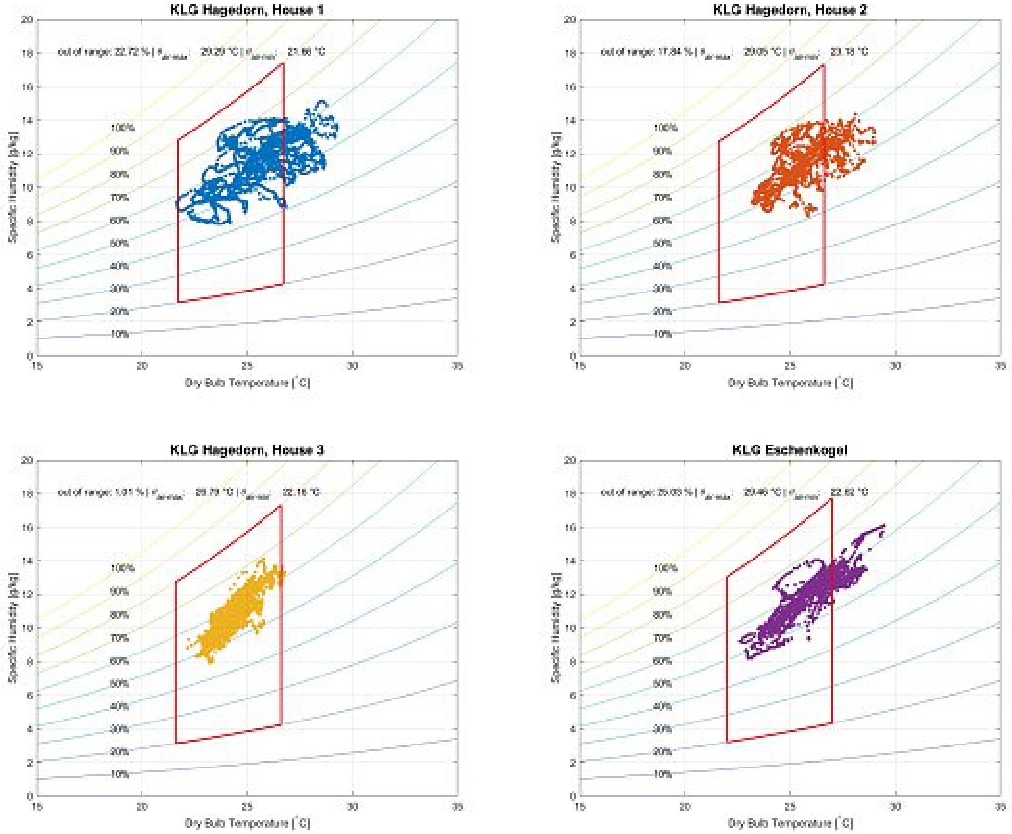


Figure 71: Psychrometric charts of August – Bedrooms 1

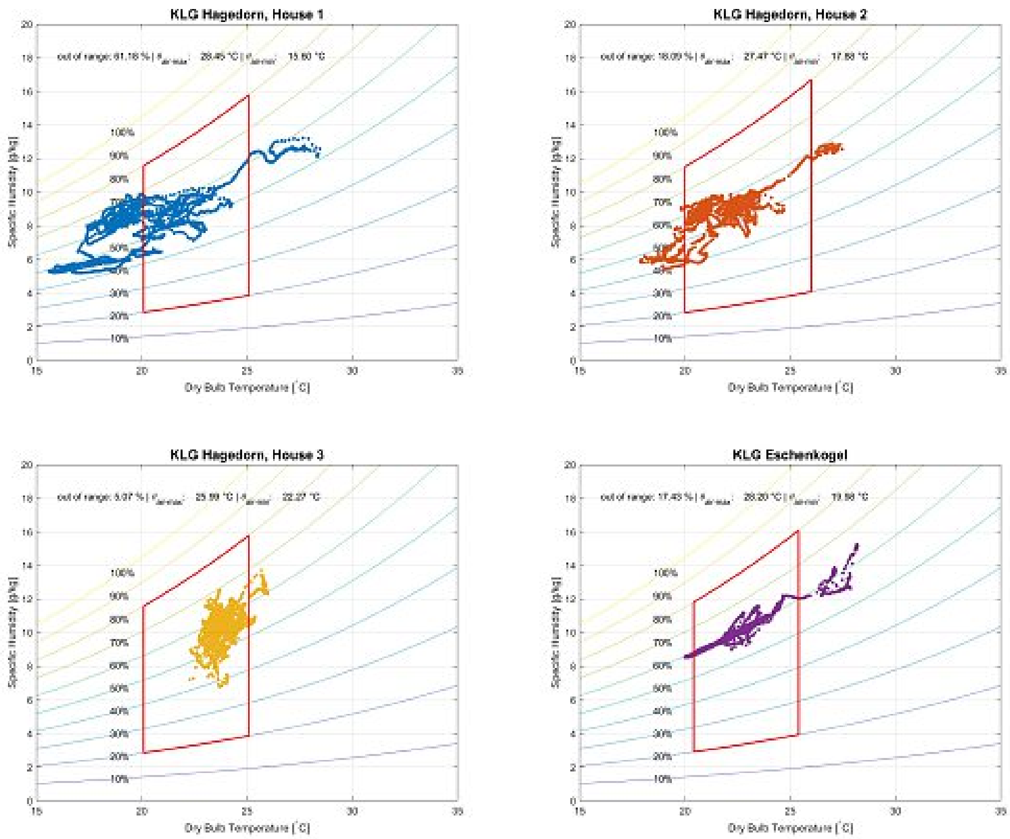


Figure 72: Psychrometric charts of September – Bedrooms 1

Overall, the number of points that does not meet the comfort criteria for the category Bedrooms 1 is higher than the one for the living rooms. Similar to the psychrometric charts of the living rooms, the percentage outside the range is overall low in August with a followed peak in September, which is illustrated in the following table:

Table 4: Percentage of points outside the comfort zone – Bedrooms 1

	July	August	September
KLG Hagedorn House 1			
< Tmin	11.1%	0.4%	55.8%
> Tmax	30.4%	22.4%	5.4%
KLG Hagedorn House 2			
< Tmin	1.6%	0.1%	13.7%
> Tmax	24.7%	17.8%	4.9%
KLG Hagedorn House 3			
< Tmin	0.0%	0.2%	0.1%
> Tmax	0.0%	1.0%	5.1%
KLG Eschenkogel			
< Tmin	0.2%	0.2%	12.7%
> Tmax	24.9%	25.0%	4.8%

KLG Hagedorn House 3 Bedroom 1 shows again the best results with a peak of 5.1% at points higher than Tmax. As this bedroom is air conditioned, the temperature was adjusted by the occupants during the whole study period. The other Bedrooms had no air conditioning and were only ventilated by natural ventilation. Especially Bedroom 1 at *KLG Hagedorn House 1* is always ventilated with a tilted window, which results in a high percentage of 55.8% lower than Tmin in September. For *KLG Hagedorn House 1*, *House 2* and *KLG Eschenkogel* the number of points above Tmax is around 20% higher than the number of points of the living rooms. This is a result of the lower density of warm air which rises to the upper floors, where all Bedrooms are situated.

4.4.3 Monthly Psychrometric Analysis – Bedrooms 2

The following graphs show the psychrometric charts for the children and guest rooms analyzed for each month of the study period. These rooms are categorized under the category of Bedrooms 2, as they are also used as sleeping rooms. They are all again located on the first floor of each house.

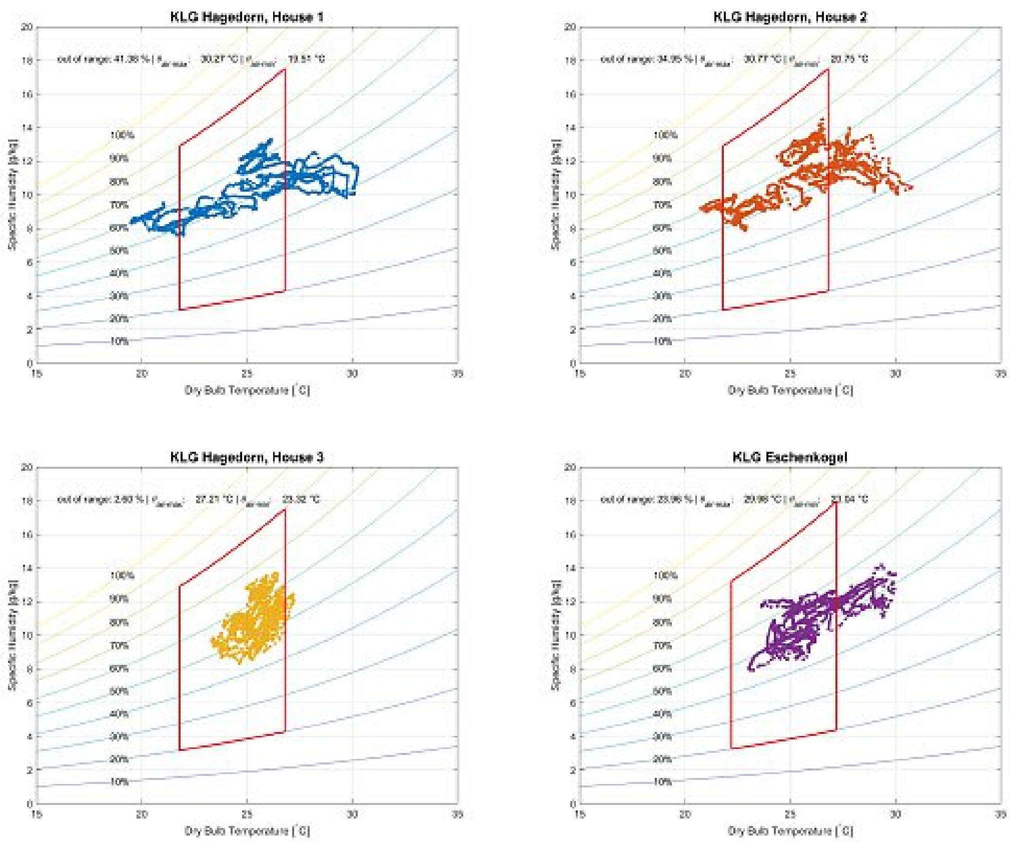


Figure 73: Psychrometric charts of July – Bedrooms 2

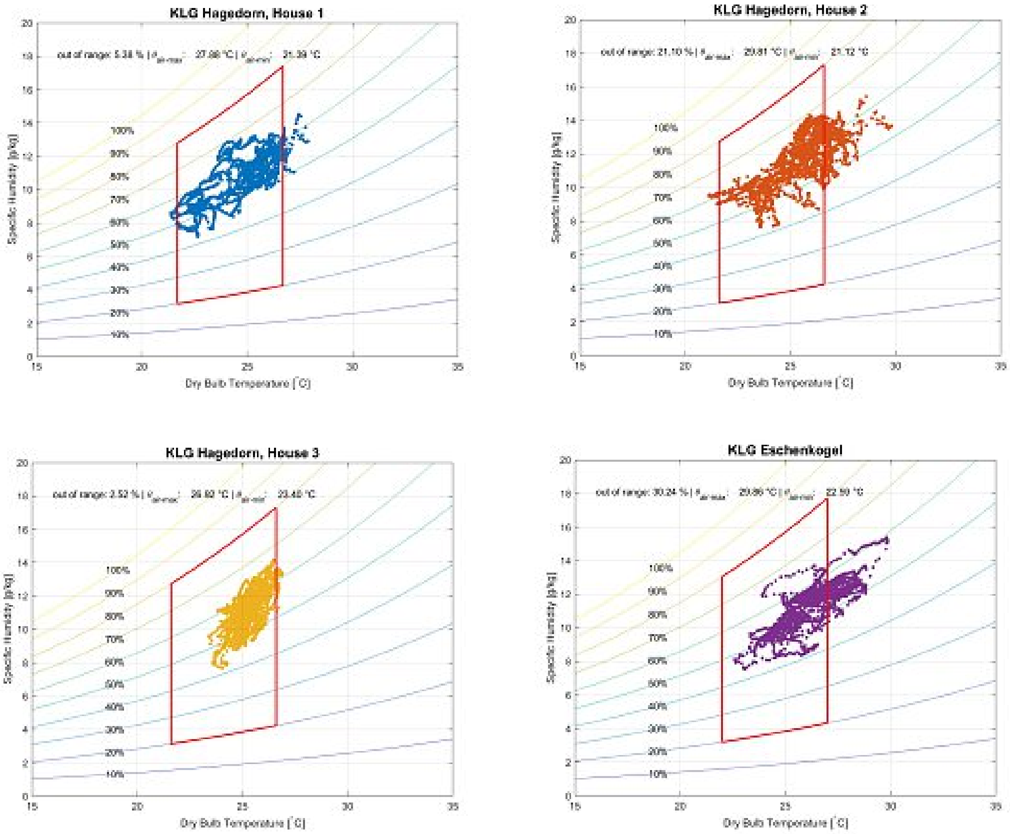


Figure 74: Psychrometric charts of August – Bedrooms 2

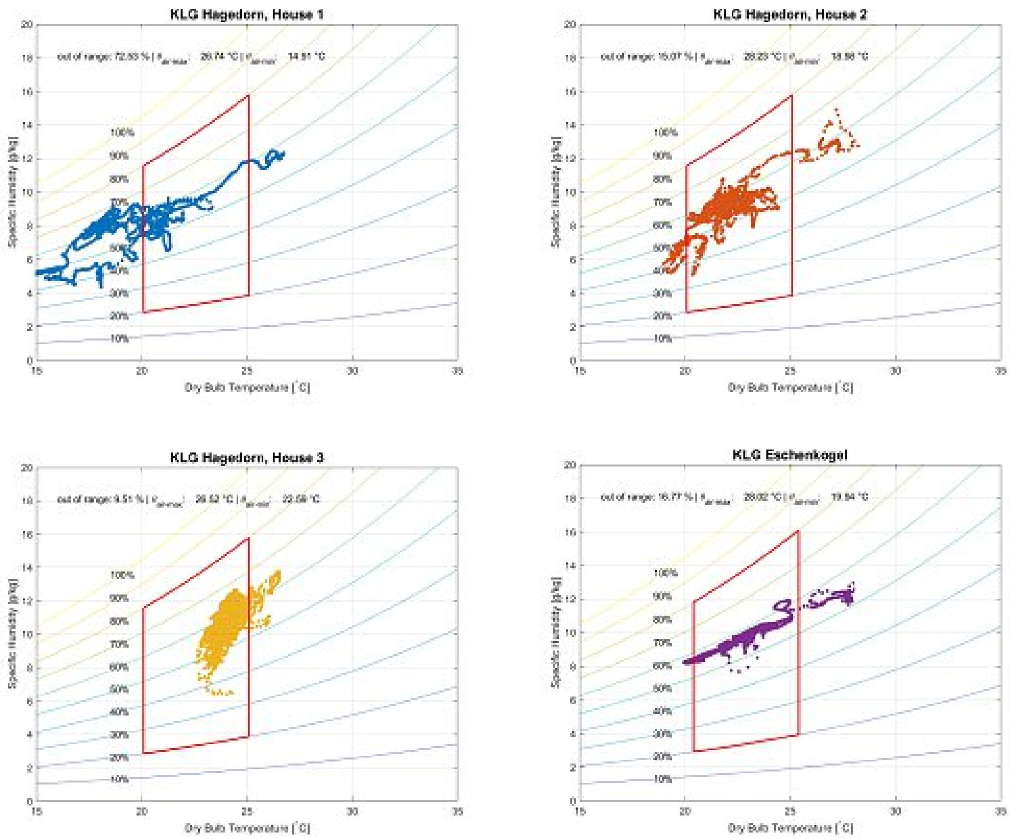


Figure 75: Psychrometric charts of September – Bedrooms 2

The percentages outside the comfort zones, similar to the ones of category Bedrooms 1, were overall higher than the one of the living rooms according to the lower density of warm air. Especially during September the graphs show a higher fluctuation of lower and higher absolute humidity values of 4 to 10g/kg at lower temperatures. Within *KLG Hagedorn House 1* Bedroom 2 these values can be found at temperatures lower than 20°C.

Table 5: Percentage of points outside the comfort zone – Bedrooms 2

	July	August	September
KLG Hagedorn House 1			
< Tmin	15.0%	1.8%	67.6%
> Tmax	26.4%	3.6%	5.0%
KLG Hagedorn House 2			
< Tmin	5.4%	0.7%	10.2%
> Tmax	29.6%	20.5%	4.9%
KLG Hagedorn House 3			
< Tmin	0.0%	0.1%	0.1%
> Tmax	2.6%	2.5%	9.5%
KLG Eschenkogel			
< Tmin	0.2%	0.2%	12.3%
> Tmax	24.0%	30.2%	4.6%

Even though Bedroom 2 at *KLG Hagedorn House 3* is not air-conditioned, the values outside the comfort zone in July and August is only about 2% higher than the ones of Bedroom 1. The other houses also show quite similar results in the categories Bedroom 1 and Bedroom 2. In September the lower outside temperature results in a higher percentage of points under Tmin.

4.5 Summer Overheating Analysis

Figure 76 to Figure 80 display the simulated operative temperature course compared to the outdoor temperature course, which were simulated by the usage of *Archiphysik 17.0*. Both are illustrated for the whole day of July 15th similar to the ÖNORM B8110-3. The operative temperature is illustrated in blue, whereas the outdoor temperature is illustrated in orange. The limit for the highest temperature of 27°C during daytime and the limit for the highest temperature during night of 25°C are portrayed in red. These limits are set as described by the Standard.

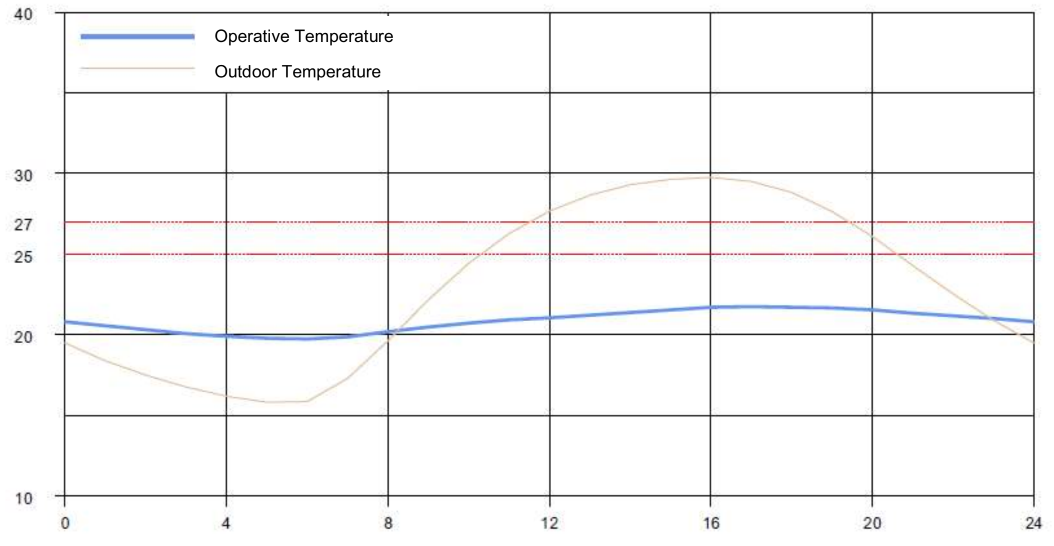


Figure 76: Simulated operative temperature and overheating limits of KLG Hagedorn House 1, Bedroom 1, exported from Archiphysik

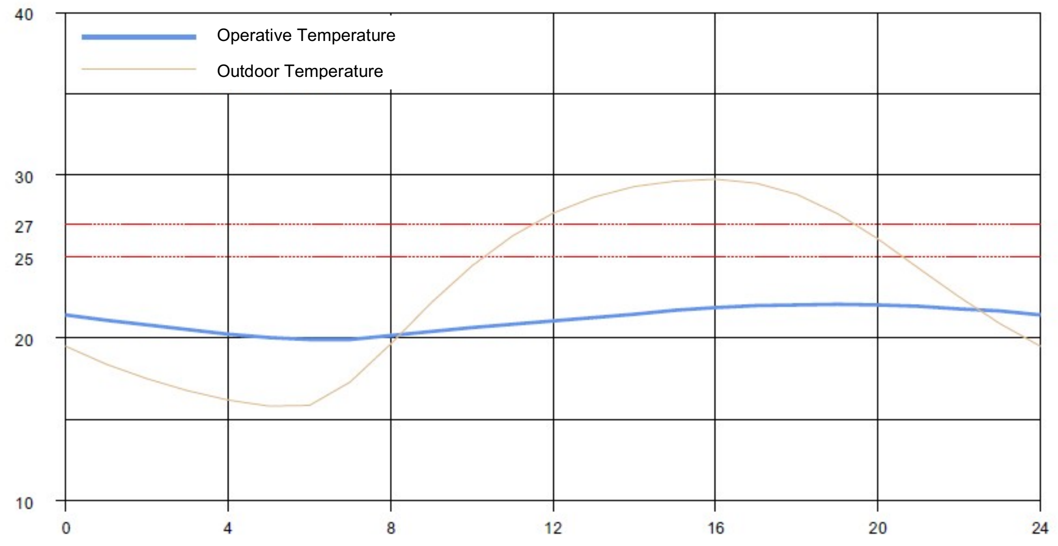


Figure 77: Simulated operative temperature and overheating limits of KLG Hagedorn House 2, Bedroom 3, exported from Archiphysik

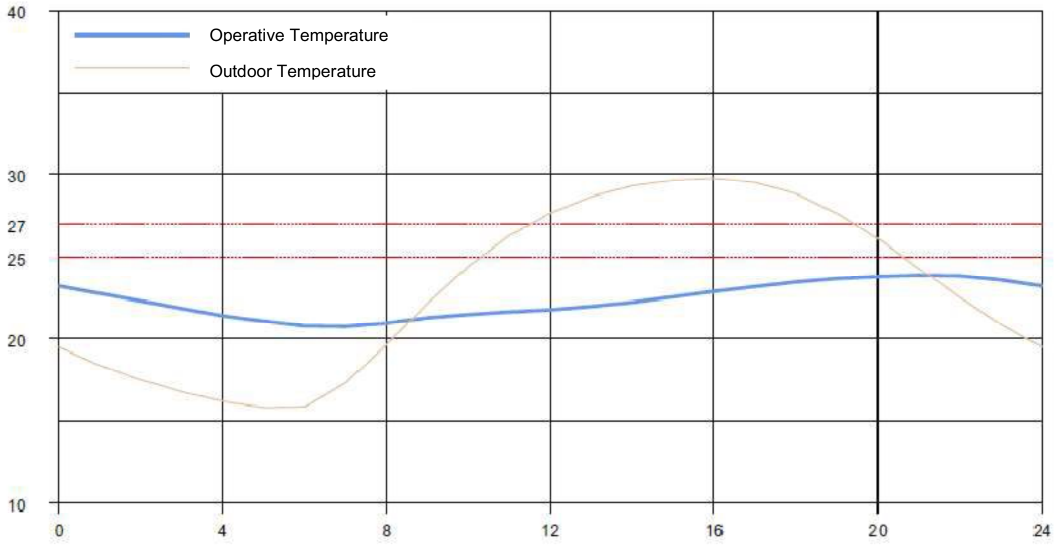


Figure 78: Simulated operative temperature and overheating limits of KLG Hagedorn House 3, Bedroom1, exported from Archiphysik

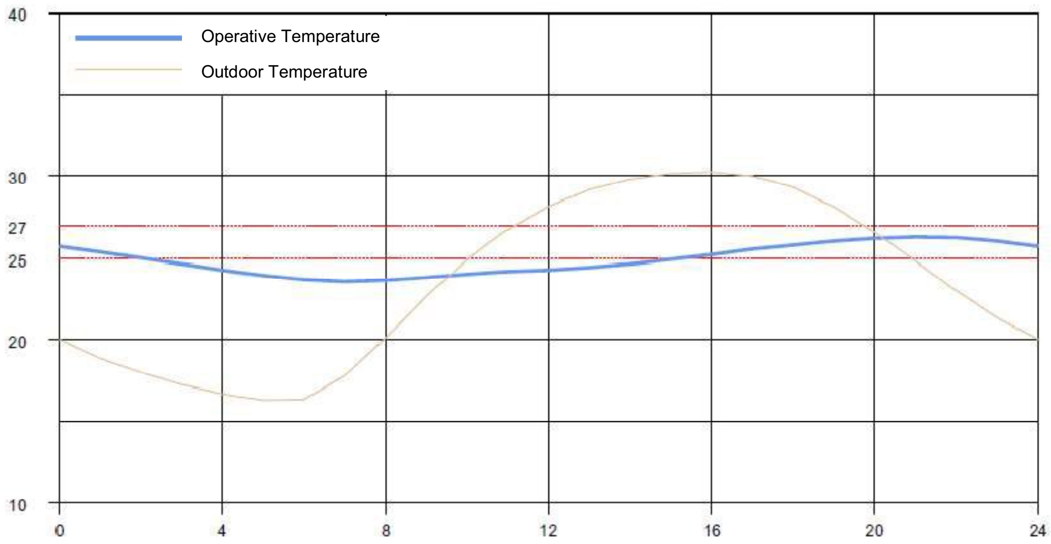


Figure 79: Simulated operative temperature and overheating limits of KLG Eschenkogel, Bedroom 2, exported from Archiphysik

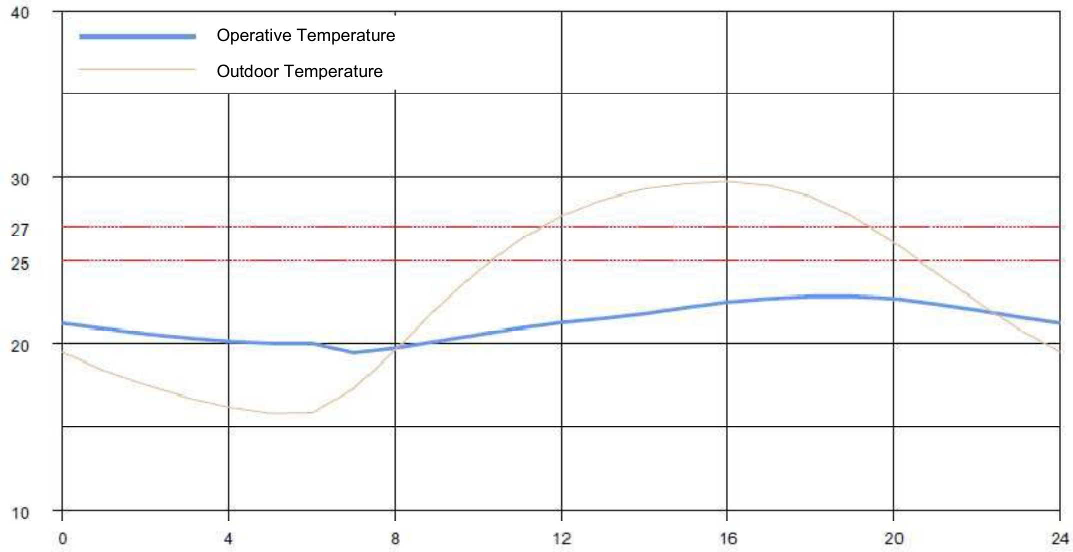


Figure 80: Simulated operative temperature and overheating limits of the temporary KLG Klagergrube, exported from Archiphysik

As *KLG Hagedorn House 1*, *House 2*, *House 3* and *the temporary KLG Klagergube* are all placed in the 22nd district of Vienna they show a similar outdoor temperature course with a daily average temperature of 23.1°C. *KLG Eschenkogel* shows a slightly higher exterior temperature with a daily average temperature of 23.6°C.

The operative temperature course of *KLG Eschenkogel* Bedroom 2 is the only course that exceeds the limit for night time of 25°C. Between 6pm and 2am the graph shows the highest values. During daytime the limit of 27°C is never crossed. The other four allotment garden dwellings neither exceed the limit of 25°C nor the limit of 27°C.

Table 6: Categories according to the simulation by Archiphysik

	Category
KLG Hagedorn House 1, Bedroom 1	A+ very suitable for summer
KLG Hagedorn House 2, Bedroom 3	A+ very suitable for summer
KLG Hagedorn House 3, Bedroom 1	A+ very suitable for summer
KLG Eschenkogel, Bedroom 2	B suitable for summer
Temporary KLG Klagergrube	A+ very suitable for summer

Table 7: Simulated highest operative temperature of the day and lowest operative temperature during night (10 pm to 6 am), Results from Archiphysik

	Operative Temperature Day	Operative Temperature Night
KLG Hagedorn House 1, Bedroom 1	21.73°C	19.74°C
KLG Hagedorn House 2, Bedroom 3	22.07°C	19.91°C
KLG Hagedorn House 3, Bedroom 1	23.85°C	20.81°C
KLG Eschenkogel, Bedroom 2	26.28°C	23.72°C
Temporary KLG Klagergrube	22.86°C	20.01°C

As illustrated in Table 6 similar to the graphs of Figure 76 to Figure 80, Bedroom 2 of *KLG Eschenkogel* is the only one outstanding, which can be explained by the missing shading in comparison to the other allotments. Still, *KLG Eschenkogel* is categorized as suitable for summer, as the most critical room is categorized B. The other allotments are all very suitable for summer according to the simulation of *Archiphysik*.

As seen in Table 7 the calculated highest operative temperature during day for *KLG Hagedorn House 3* is higher than the ones for the other two allotments in the *KLG Hagedorn*. According to the owners of *KLG Hagedorn House 3*, Bedroom 1 has a tendency for overheating during summertime, so they installed an air conditioning system. In comparison to the other two allotments of *KLG Hagedorn,* the simulation with *Archiphysik* indicates a slightly worse performance of *House 3* during the summer period, which is a result of the higher storage capacity of the construction compenents and the components orientation.

According to the simulations, all five allotment garden dwellings are suitable or very suitable for summer and show no tendency for summer overheating. Thus, they would not require any extra cooling devices as described in the Standard.

4.6 Summary

Overall, the indoor temperatures and relative humidity values of the five allotments show a great variety in their performances. The indoor temperature range between 23 and 26°C, as stated in the ÖNORM EN 16798-1, and the relative humidity range of 20 to 80%, described in the ASHRAE Standard, indicate a high thermal comfort. A range of 40 to 60% RH is optimal to minimize risks to human health (Sterling, Arundel, Sterling, 1985).

KLG Hagedorn House 1 holds the dedication of ELKW and thus can be used for year-round living. It was constructed as a massive brick construction with later added exterior insulation. Still, this allotment is only used part time during the summer period during daytime. Throughout the whole study period, the two bedrooms were always ventilated by tilted windows and the terrace door to the living room was opened while the house was occasionally used. These ventilation patterns as well as the lack of heating can be especially observed in the overall temperature profile of *KLG Hagedorn House 1*. It shows higher frequencies at lower temperatures of ≤20°C than the other three allotments for year-round living, which are all used as primary residences. These frequencies can be observed for all three monitored rooms. Within the calculation of the neutrality temperature it is visible, that *KLG Hagedorn House 1* especially performs worse when the outside temperature drops. In comparison to *KLG Hagedorn House 2*, which was built during the same time with similar materials, the difference between the percentages inside the neutrality range in September lies at 55%. The overall relative humidity measurements peak at 60% RH showing also a wider range of measured values than the other allotments. It is possible, that the exterior walls already contain a higher amount of stored moisture content. Therefore, a reduced insulation capability would be possible. These wide ranges of temperature and relative humidity are also displayed in the psychrometric charts, which indicate that especially the two bedrooms tend to show values over Tmax as they are situated on the first floor. They are exposed to a higher overheating risk than the living room. Still, the values show a better performance during higher outside temperatures. The simulation of *Archiphysik* also describes a '*very suitable*' performance for summer overheating. To summarize, the *KLG Hagedorn House 1* shows a better performance at higher outside temperatures and lower outside relative humidity values. This underlines the original purpose of this allotment, as it was planned as a summer accommodation, even though the dedication of ELKW allows it to be used for year-round living.

KLG Hagedorn House 2 was built during the same construction period as *KLG Hagedorn House 1* as a massive brick construction and later added exterior insulation. Today it is used as a primary residence by the owners and therefore ventilated and heated in a controlled way, even though, it was planned as a summer accommodation similar to *House 1*. It slightly shows better results than *House 1* with higher frequencies between the temperature range of 23 and 26°C, which can be explained by the periodic ventilation and heating procedure of the owners. Also, the calculation of the neutrality temperature displays a higher number of values within the neutrality temperature range: 86% in July, 95% in August and 77% in September. Further, the temperature profile of *KLG Hagedorn House 2* indicates a better performance at higher outside temperatures. The relative humidity values peak at 55% relative humidity, whereas all values can be found within the range of 40 to 70%. Therefore, the comfort according to the ASHRAE Standard 55 and the minimization of health risk is mostly given. No risk of summer overheating and a category of A+ by the simulation of *Archiphyik* further describe the well functioning performance during higher outside temperatures. As *House 2* is used for year-round living and therefore periodically ventilated and heated, an acceptable performance during lower outside temperatures and higher outside relative humidity values can be presumed.

The newest allotment *KLG Hagedorn House 3*, which was built in 2009 in a construction of Porotherm and exterior insulation, presents superior results for the whole study period. 90% of temperature measurements can be found within the given range for all room categories. KLG *Hagedorn House 3* is the only one of the five allotments, which was built after an energy certificate was submitted and was already planned for year-round living at the beginning of the planning procedure. It also contains an air-conditioning system at Bedroom 1. *House 3* solely shows most measured values within the wanted range during September. The same trend can be observed for the calculation of the neutrality temperature ranges, as 99% of measured values in July, 100% in August and 95% in September are within the range, exceeding all values of the other allotments. Even though it is the newest allotment, the measured relative humidity values show similar results to *KLG Hagedorn House 2* as both are ventilated by the owners periodically. The psychrometric charts underline the findings during the analysis of the temperature and relative humidity profile, as most values can be found within the comfort window. Therefore, the overall performance of *KLG Hagedorn House 3* is stable during the three analyzed months. This is further emphasized by the categorization of A+ by the summer overheating simulation. All measured values, as well as the simulation, further denote that *KLG Hagedorn House 3* was already planned as a house for year-round living.

Within this study, *KLG Eschenkogel* is the only allotment which was built in a wooden construction and is used for year-round living. At the beginning of the construction of *KLG Eschenkogel* the dwelling was only planned as a summer accommodation. About 50% of the temperature measurements can be found within the presumed range. Especially the two bedrooms show similar results as they show a similar gross area, are ventilated at the same time and are also exposed to the same direction and amount of sun. The measured values within the neutrality temperature range indicate a better performance at higher outside temperatures. The relative humidity measurements display a smaller range of values and higher peaks with frequencies of 90% at 60% relative humidity, which are further displayed in the psychrometric analysis. These values are a result of the well functioning wooden construction with exterior insulation. Therefore, they show a better moisture performance than the massive brick constructions of the other allotments for year-round living. The psychrometric charts display a better performance during the months of July and August rather than September, which further underline that this allotment was not planned for year-round living from the beginning of the planning procedure. Still, the allotment *KLG Eschenkogel* is the only one categorized as B suitable for summer according to the *Archiphysik* simulation. This is a result of the missing shading compared to the other allotments. These results can be invalidated by the analysis of measured temperature values.

Overall, the *temporary KLG Klagergrube* displays a rather similar temperature distribution to the outside temperature. The lack of insulation of the wooden construction, as well as high ventilation rates during high outside temperatures, generate this distribution. The dedication of temporary EKL allows it to be used only during the summer period. As this allotment has no fresh water supply, no electricity and is only constructed as a small wooden cottage, it is partly used during the daytime. This resembles in the overall temperature distribution bins as the frequency of 40% peaks at temperatures ≤20°C similar to the outside temperature distribution. Also, the percentages inside the neutrality range show the overall lowest values of 56% in July, 57% in August and 31% in September. These values emphasize the preferred usage during daytime. Still, the measured relative humidity values can be found within a range of 30 to 70% and therefore are within the comfort range according to the ASHRAE Standard 55. The overall fluctuation of temperature and relative humidity can be further observed during the psychrometric analysis with a trend of values lower than Tmin during all three months of the study period. Again, this resembles the overall outside values measured at the *temporary KLG Klagergrube*.

5 CONCLUSION

5.1 Scientific Contribution

The density of buildings in urbanized areas has increased worldwide. The same trend can be observed in Vienna by a rapid inner-city densification. Allotment garden dwellings play valuable a role within the local green spaces of Vienna and can further improve the temperature performance of the whole city (Bedlan, Follak, Moyses, 2019).

Due to the small building volume, low room heights and a lack of opportunities to use them for the whole year, allotment garden dwellings can be differentiated from regular single family houses. The current building requirements for allotment houses focus on similar heterogeneous structures rather than their indoor comfort performance.

This thesis provides data of a sample of five different allotment residences and their thermal comfort performances. In general, allotments are primarily used during the summer period. Four of the five studied allotment garden dwellings were originally planned as summer cottages for a usage from April 15th to October 15th. Nevertheless, three of these five allotments are now used for year-round living (*KLG Hagedorn House 2, KLG Hagedorn House 3* and *KLG Eschenkogel*), whereas the other two (*KLG Hagedorn House 1* and *the temporary KLG Klagergube*) are only occupied occasionally during daytime. The five allotments were monitored from the beginning of July to the end of September collecting data for the inside and outside temperature and for relative humidity.

The allotment garden dwellings display a great variety in temperature and relative humidity performances. All five houses display a high number of values within the comfort zone in August with a significant decrease in September. The four houses originally planned as summer cottages, show acceptable results for the summer time but indicate a decreasing thermal comfort with lower outside temperatures. Only *KLG Hagedorn House 3*, which is the newest building and was originally planned for year-round living, shows most measurement values within the wanted comfort window ranges.

Overall, a recommendable addition of exterior shadings at most windows, would further improve the interior thermal comfort during summer. The indoor conditions especially within *KLG Hagedorn House 1* and the *temporary KLG Klagergrube* could be further improved. For *KLG Hagedorn House 1* the ventilation mannerism could be reconsidered and balanced according to the owners preferences. The *temporary KLG Klagergrube* has no exterior insulation and is therefore never used during autumn or winter. For an extended usage, exterior insulation and a heating device would further improve the overall thermal comfort performance.

5.2 Future Research

As a result of global warming, the number of studies towards thermal comfort and thermal performance of buildings is increasing. "*As architects and engineers think of ways to improve the user's environmental comfort while improving the performance of buildings, it is imperative they consider that people spend between 80% and 90% of their days indoors.*" (Rupp, Vásquez, Lamberts, 2015) Therefore, closer studies of people's daily impact and need on thermal comfort are in great demand. As allotment garden dwellings nowadays create a year-round living space, the thermal comfort should be researched in greater detail.

This thesis displays a case study of five different allotments, built in different construction periods and with different occupation times. Still, Viennese allotments show a great variety of garden dwellings. Therefore, a study containing a large number of allotments, monitored over a longer period of time could provide even more information about the thermal comfort performance of different allotment garden dwellings. As this thesis focuses on the summer period only, this period could be further expanded for a thermal comfort analysis of the whole year.

As these garden dwellings provide extra green space for Vienna during a time of inner-city densification, the impact of allotments to a better heat balance within cities would constitute another interesting field for future research.

5 INDEX

5.2 List of Figures

5.3 List of Tables

5.4 List of Equations

6 LITERATURE

ASHRAE Standard 55. (2017) *Thermal Environmental Conditions for Human Occupancy*.

Auliciems, A., Szokolay, S. (1997) *Thermal Comfort*.

Autengruber, P. (2018) *Die Wiener Kleingärten: Von den Anfängen bis zur Gegenwart*.

Bedlan, G., Follak, S., Moyses, A. (2019) *Studie zur Biodiversität der Wiener Kleingärten. 2016 – 2019.*

Bundesgesetz vom 16. Dezember 1958 über die Regelung des Kleingartenwesens (Kleingartengesetz) (StF), BGBl. Nr. 6/1959.

Battisti, K., Somogyváry, B. (2018) *Archiphysik 16. Bauphysikalische Berechnungen für energieeffiziente Gebäude*.

Fanger, P. (1970) *Thermal comfort. Analysis and applications in environmental engineering*.

Kuzmich, F., Municipal Department 19 (Ed) (2016) *Kleingartenhaus in Wien. Überarbeitete Neuauflage der im Auftrag der MA19 von Roland Hagmüller verfassten Broschüre "Kleingartenhaus". Publiziert 1998 von der Stadt Wien (MA18) als Band 63 der "Beiträge zur Stadtforschung, Stadtentwicklung und Stadtgestaltung".*

Gesetz über Kleingärten in Wien (Wiener Kleingartengesetz 1996 – WKIG 1996), LGBl. Nr. 9/1996.

Gesetz über Kleingärten in Wien (Wiener Kleingartengesetz 1996 – WKIG 1996), LGBI. Nr. 11/1959.

Gesetz über Kleingärten in Wien (Wiener Kleingartengesetz 1996 – WKIG 1996), LGBl. Nr. 12/1999.

Hens, H. (2012) *Building physics - heat, air and moisture: fundamentals and engineering methods with examples and exercises*.

Kumar, S.,Mathur, J., Mathur, S., Singh, M., Loftness, V. (2016) *An adaptive approach to define thermal comfort zones on psychrometric chart for naturally ventilated buildings in composite climate of India*. In: Building and Environment 109, pp. 135–153.

Kral, M. (1992) *Das Wiener Kleingartenwesen. Entwicklung, gegenwärtige Situation und zukünftige Tendenzen*. Diploma thesis: Vienna University ofeconomics and business.

Krec, K. (2006) *Bewertung der Sommertauglichkeit von Gebäuden.*

Martinho da Silva, I., Oliveira Fernandes, C., Castiglione, B. and Costa, L. (2016) *Characteristics and motivations of potential users of urban allotment gardens: The case of Vila Nova de Gaia municipal network of urban allotment gardens*. In: Urban Forestry & Urban Greening 20, pp. 56–64.

Municipal Department 22 (Ed) (2018) *Urban Heat Island Strategy. City of Vienna.*

OIB, Österreichisches Institut für Bautechnik (2019) *OIB Richtlinie 6: Engergieeinsparung und Wärmeschutz.*

ÖNORM B8110-3. (2020) *Thermal protection in building construction – Part 3: Determination of the operating temperature in summer (Prevention of summerly overheating).*

ÖNORM EN 16798-1. (2019) *Energy performance of buildings – Ventilation for buildings – Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics – Module M1-6.*

ÖNORM H 12831-1. (2018) *Heating systems in buildings – Method for calculation of the design heat load – National supplement to ÖNORM EN 12831-1.*

ÖNORM EN ISO 7730. (2006) *Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.*

Riccabona, C. (2003) *Baukonstruktionslehre: 4. Bauphysik.*

Rupp, R. F., Vásquez, N. G. and Lamberts, R. (2015) *A review of human thermal comfort in the built environment*. In: Energy and Buildings 105, pp. 178-205.

Carlucci, S. (2013) *Thermal Comfort Assessment of Buildings.*

Sterling, E. M., Arundel, A., Sterling, P.T. (1985) *Criteria for Human Exposure to Humidity in Occupied Buildings.* In: ASHRAE Transactions, pp.611-622.

Szokolay, S. (2014) *Introduction to architectural science. The basis of sustainable design.*

Wiener Stadtentwicklungs-, Stadtplanungs- und Baugesetzbuch (Bauordnung für Wien – BO für Wien), StF.: LGBl. Nr. 11/1930.

7 APPENDIX

A. Photos

A.1. Logger Locations KLG Hagedorn House 1

Figure A-1: Logger #798500 Living Room

Figure A-2: Logger #805729 Living Room

Figure A-3: Logger #805737 Bedroom 1

Figure A-4: Logger #805738 Bedroom 2

A.2. Logger Locations KLG Hagedorn House 2

Figure A-5: Logger #805715 Living Room

Figure A-6: Logger #805724 Living Room

Figure A-7: Logger #1124917 Bedroom 1

Figure A-8: Logger #809170 Bedroom 2

Figure A-9: Logger #805734 Bedroom 3

A.3. Logger Locations KLG Hagedorn House 3

Figure A-10: Logger #809179 Living Room

Figure A-11: Logger #1124921 Living Room

Figure A-12: Logger #1124922 Bedroom 1

Figure A-13: Logger #809160 Bedroom 2

A.4. Logger Locations KLG Eschenkogel

Figure A-14: Logger #1124916 Living Room

Figure A-15: Logger #686202 Living Room

Figure A-16: Logger #809168 Living Room

Figure A-17: Logger #1124923 Bedroom 1

Figure A-18: Logger #994109 Bedroom 2

A.5. Logger Locations Temporary KLG Klagergrube

Figure A-19: Logger #798500 Main Room

Figure A-20: Logger #805729 Main Room

Figure A-21: Logger #805737 Main Room

B. Graphs

B.1. Neutrality Temperature KLG Hagedorn House 1

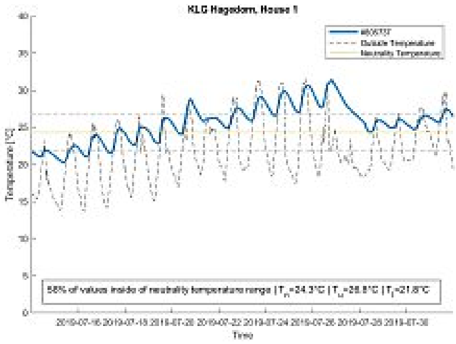


Figure A-22: Bedroom 1, July

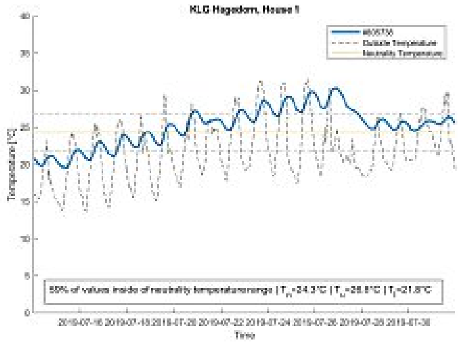


Figure A-23: Bedroom 2, July

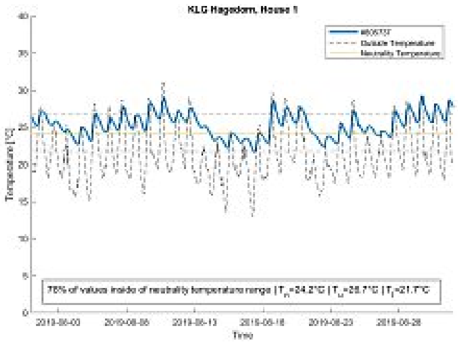


Figure A-24: Bedroom 1, August

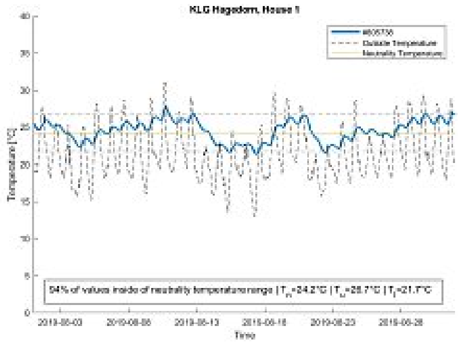


Figure A-25: Bedroom 2, August

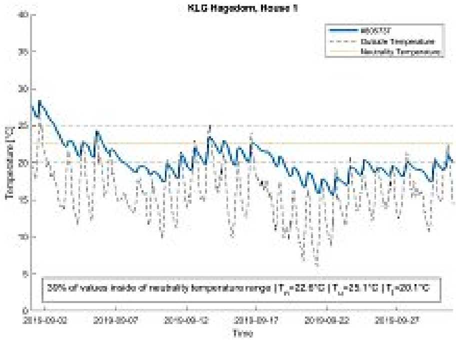


Figure A-26: Bedroom 1, September

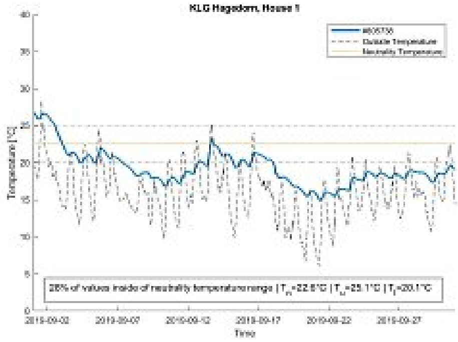


Figure A-27: Bedroom 2, September

B.2. Neutrality Temperature KLG Hagedorn House 2

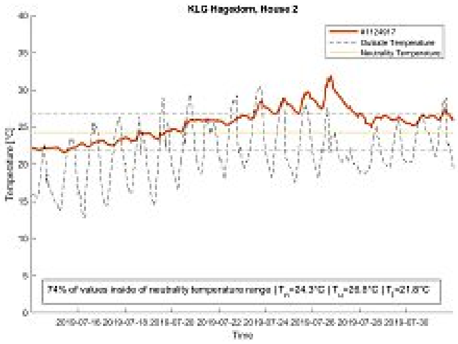


Figure A-28: Bedroom 1, July

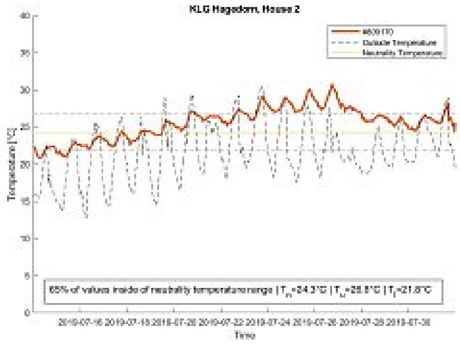


Figure A-29: Bedroom 2, July

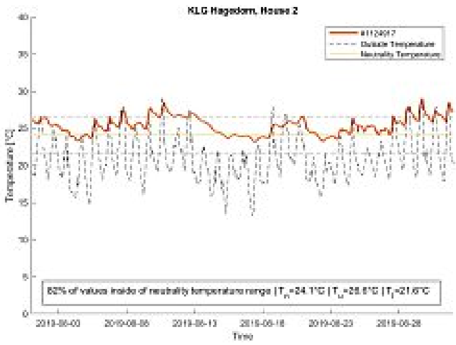


Figure A-30: Bedroom 1, August

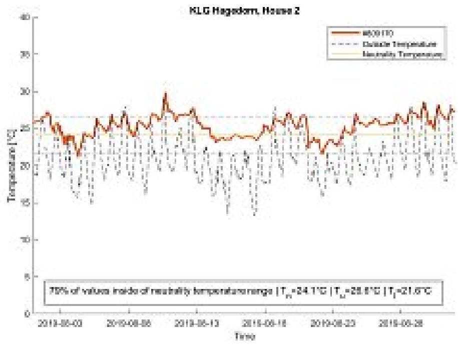


Figure A-31: Bedroom 2, August

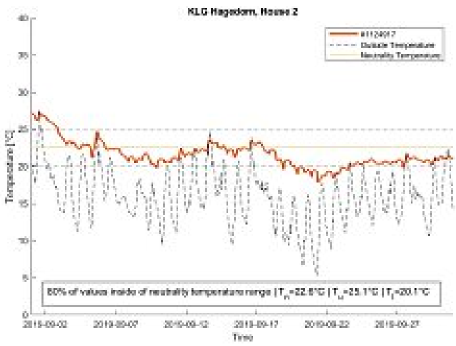


Figure A-32: Bedroom 1, September

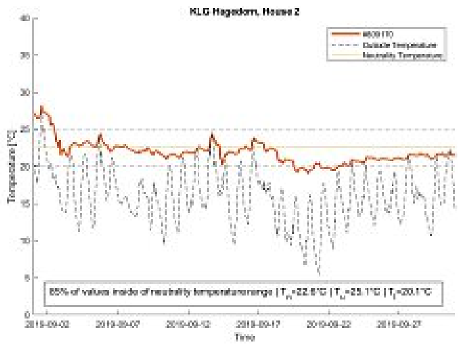


Figure A-33: Bedroom 2, September

B.3. Neutrality Temperature KLG Hagedorn House 3

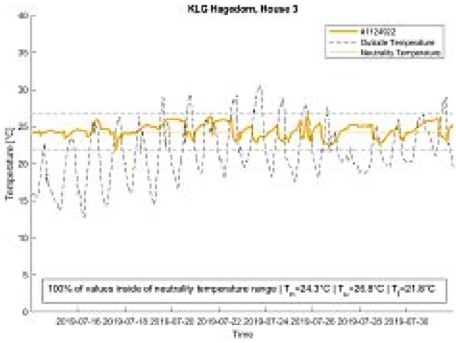


Figure A-34: Bedroom 1, July

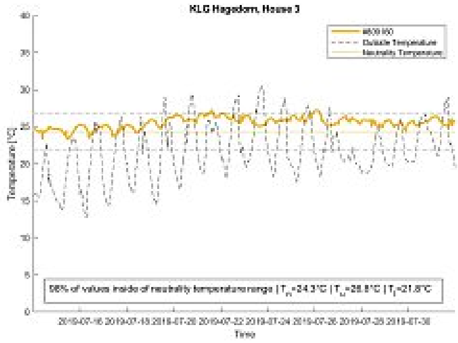


Figure A-35: Bedroom 2, July

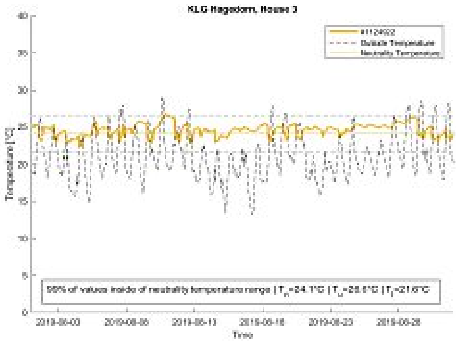


Figure A-36: Bedroom 1, August

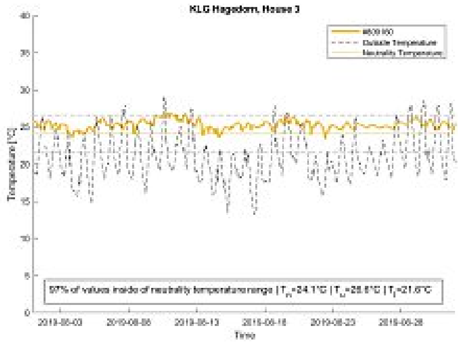


Figure A-37: Bedroom 2, August

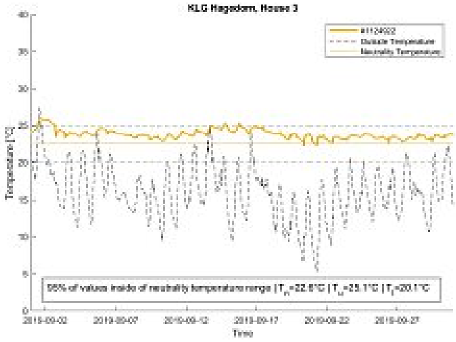


Figure A-38: Bedroom 1, September

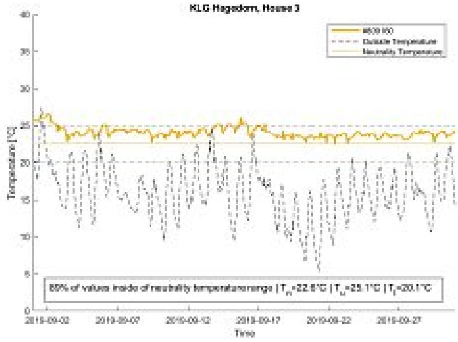


Figure A-39: Bedroom 2, September

B.4. Neutrality Temperature KLG Eschenkogel

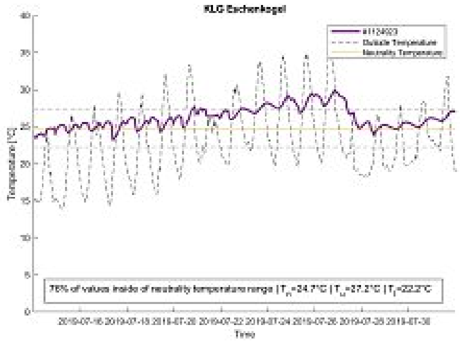


Figure A-40: Bedroom 1, July

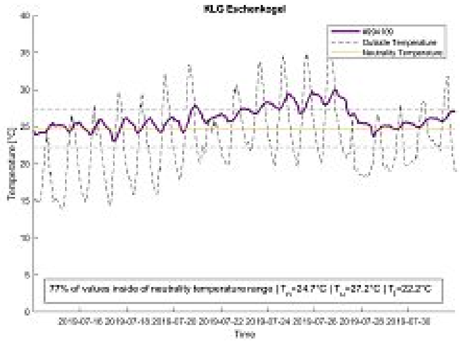


Figure A-41: Bedroom 2, July

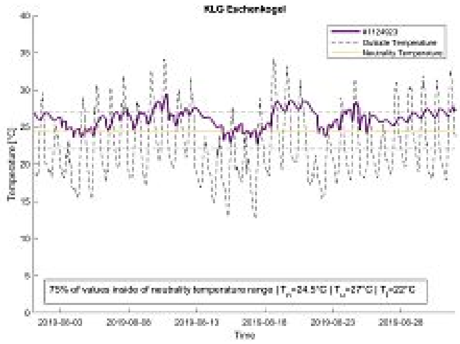


Figure A-42: Bedroom 1, August

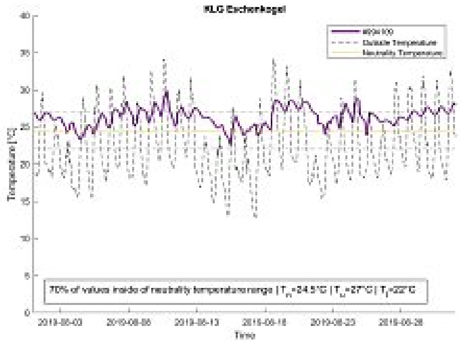


Figure A-43: Bedroom 2, August

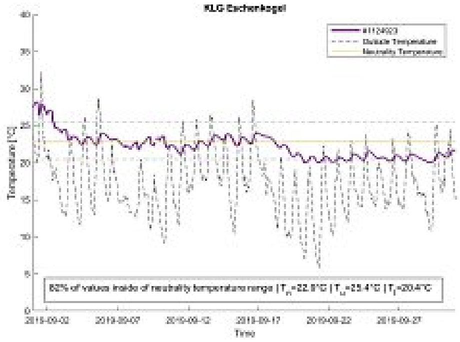


Figure A-44: Bedroom 1, September

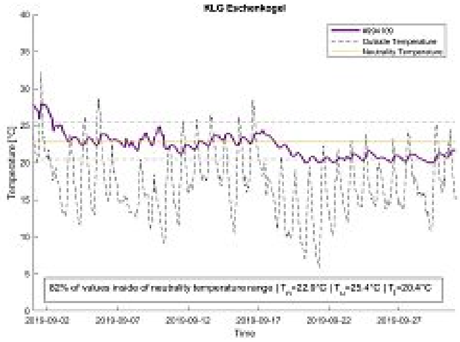


Figure A-45: Bedroom 2, September

C. Simulation

C.1. Summer Overheating KLG Hagedorn House 1

12

ArchiPHYSIK - A-NULL - SCHULVERSION

Beurteilung der Sommertauglichkeit

Bedroom 1 001

KLG Hagedorn House 1

Standort

1220 Wien-Donaustadt

Plangrundlagen

00.00.0000

Nutzung

Wohnung, Gästezimmer in Pensionen und Hotels

Verwendung eines Standard Raum-Nutzungsprofils aus ON B 8110-3

Annahmen zur Berechnung

Berechnungsgrundlage	ÖN B 8110-3:2012-03	**Hauptraum, detailliert**
Bauteile	EN ISO 6946:2003-10	
Fenster	EN ISO 10077-1:2006-12	
RLT	ON H 5057:2011-03-01	

Tag für die Berechnung des Nachweises

standard	15. Juli
Tagesmittelwert der Aussentemperatur	23,10 °C

Berechnungsvoraussetzung ist, dass keine wie immer gearteten Strömungsbehinderungen wie beispielsweise Insektenschutzgitter oder Vorhänge vorhanden sind. Zur Erreichung der erforderlichen Tag- und Nachtlüftung sind entsprechende Voraussetzungen für eine erhöhte natürliche Belüftung, wie öffenbare Fenster, erforderlichenfalls schalldämmende Lüftungseinrichtungen u. dgl., anzustreben. Zur Sicherstellung eines ausreichenden Luftaustausches bzw. einer ausreichenden Querlüftung zwischen den betrachtn Räumen sind entsprechende planerische Maßnahmen zur Einhaltung der erforderlichen Lüftungsquerschnitte zu setzen. Die Ermittlung selbst bezieht sich auf diesen einen Raum.

A+	A	B	C	D
sehr gut sommertauglich	gut sommertauglich	sommertauglich	bedingt sommertauglich	nicht sommertauglich

Operative Temperatur — **21,73 °C** (erforderlich: 27,00 °C)

min. operative Temperatur im Nachtzeitraum (22:00 Uhr - 6:00 Uhr) — **19,74 °C** (erforderlich: 25,00 °C)

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020

12-2

Beurteilung der Sommertauglichkeit

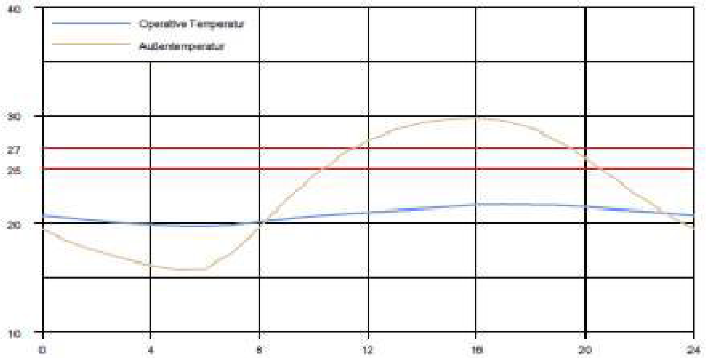
KLG Hagedorn House 1 - 001 - Bedroom 1

Immissionsflächenbezogene speicherwirksame Masse **4.574,89 kg/m²**

Immissionsfläche gesamt	0,50 m²
Fensterfläche	1,92 m²
Immisionsflächenbezogener stündlicher Luftvolumenstrom	136,73 m³/(h m²)
Speichermasse der Einrichtung/Ausstattung	38,00 kg/m²

Report

Tagesgang T a und operative Temperatur



h	T a °C	T op °C
0	19,51	20,81
1	18,38	20,57
2	17,47	20,32
3	16,73	20,08
4	16,17	19,88
5	15,82	19,77
6	15,86	19,74
7	17,27	19,87
8	19,61	20,17
9	22,14	20,47
10	24,43	20,72
11	26,28	20,91
12	27,68	21,05
13	28,67	21,20
14	29,30	21,36
15	29,65	21,55
16	29,74	21,68
17	29,50	21,73
18	28,80	21,70
19	27,62	21,65
20	26,06	21,52
21	24,29	21,34
22	22,51	21,17
23	20,89	21,01
24	19,51	20,81

Tagesmittelwert der Aussentemperatur **23,10 °C**

Lüftung und Raumlufttechnik

Raumlufttechnik

Fensterlüftung

Luftwechsel (Tag)	**0,40 1/h**
Luftwechsel (Nacht)	**1,50 1/h**
Luftwechsel bei Luftdichtigkeitsprüfung (n50)	**1,50 1/h**

Tagesgang Luftvolumenstrom nicht Standard

Raumgeometrie und Oberflächen

Bezugsfläche	Wohnnutzfläche	Netto-Raumvolumen	Fensteranteil
20,10 m2	**20,10 m2**	**45,57 m3**	**9,55 %**

Typ	Btl-Nr.	Bezeichnung	A m²	$m_{w,B,A}$ kg/m²	Speichermasse kg
ADh	R01	Roof + Roof annex	5,07	0,00	0,00
ADh	R01	Roof + Roof annex	6,90	0,00	0,00

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020

12-3

Beurteilung der Sommertauglichkeit

KLG Hagedorn House 1 - 001 - Bedroom 1

Typ	Btl-Nr.	Bezeichnung	A m²	$m_{wB,A}$ kg/m²	Speichermasse kg
ADh	R01	Roof + Roof annex	8,11	0,00	0,00
ADh	R01	Roof + Roof annex	11,04	0,00	0,00
AF	W07	Window First Floor South	0,48	0,00	0,00
AF	W07	Window First Floor South	0,48	0,00	0,00
AF	W07	Window First Floor South	0,48	0,00	0,00
AF	W07	Window First Floor South	0,48	0,00	0,00
AW	EW01	Exterior Wall	5,84	72,49	423,39
AW	EW01	Exterior Wall	2,76	72,49	200,74
AW	EW01	Exterior Wall	1,70	15,57	26,55
AW	EW01	Exterior Wall	1,70	15,57	26,55
AW	EW01	Exterior Wall	1,58	15,57	24,60
AW	EW01	Exterior Wall	1,20	72,49	86,99
IDo	F03	Indoor slab	20,10	17,88	359,51
IW	IW01	Interior Wall 1	1,36	74,35	101,12
IW	IW02	Interior Wall 2	3,48	50,67	176,34
IW	IW02	Interior Wall 2	0,68	50,67	34,45
IW	IW02	Interior Wall 2	1,25	50,67	63,34
		Einrichtung	20,10	38,00	763,80
			Ø	24,13	2.287,45

Bauteile mit solarem Eintrag

Transp. Bauteile Süd-Ost, 0° (Z ON: 1,14)

Anzahl	Btl-Nr.	Bezeichnung	A_{AL} m²	f_G	Höhe m	Breite m	Öff/Kippw. m	g-Wert	F_{Sc}	F_C
1x	W07	Window First Floor South	0,48	0,70	0,60	0,80	O	0,61	0,92	0,62

Transp. Bauteile Süd, 0° (Z ON: 1,00)

Anzahl	Btl-Nr.	Bezeichnung	A_{AL} m²	f_G	Höhe m	Breite m	Öff/Kippw. m	g-Wert	F_{Sc}	F_C
1x	W07	Window First Floor South	0,48	0,70	0,60	0,80	O	0,61	0,90	0,62
1x	W07	Window First Floor South	0,48	0,70	0,60	0,80	O	0,61	0,90	0,62

Transp. Bauteile Süd-West, 0° (Z ON: 1,14)

Anzahl	Btl-Nr.	Bezeichnung	A_{AL} m²	f_G	Höhe m	Breite m	Öff/Kippw. m	g-Wert	F_{Sc}	F_C
1x	W07	Window First Floor South	0,48	0,70	0,60	0,80	O	0,61	0,92	0,62

Verschattung und Sonnenschutz

Transp. Bauteile Süd-Ost, 0°

		Transmission/Reflexion			Sonnenschutz				Verschattung		
Btl-Nr.	Bezeichnung	$\tau_{e,B}$	$\rho_{e,B}$	ε	Lage	Lichtdl.	Farbe	w7h	Fh	Fo	Ff
W07	Window First Floor South	0,20	0,60	0,00	I	M	W	ja	1,00	0,92	1,00

Beurteilung der Sommertauglichkeit

KLG Hagedorn House 1 - 001 - Bedroom 1

Transp. Bauteile Süd, 0°

		Transmission/Reflexion				Sonnenschutz			Verschattung		
Btl-Nr.	Bezeichnung	$\tau_{e,s}$	$\rho_{e,s}$	ε	Lage	Lichtdl.	Farbe	v7h	Fh	Fo	Ff
W07	Window First Floor South	0,20	0,60	0,00	I	M	W	ja	1,00	0,90	1,00
W07	Window First Floor South	0,20	0,60	0,00	I	M	W	ja	1,00	0,90	1,00

Transp. Bauteile Süd-West, 0°

		Transmission/Reflexion				Sonnenschutz			Verschattung		
Btl-Nr.	Bezeichnung	$\tau_{e,s}$	$\rho_{e,s}$	ε	Lage	Lichtdl.	Farbe	v7h	Fh	Fo	Ff
W07	Window First Floor South	0,20	0,60	0,00	I	M	W	ja	1,00	0,92	1,00

Legende zu den Tabellen der transp. Bauteile

Öffnungstyp:	Sonnenschutz - Lage:	Sonnenschutz - Lichtdurchlass:	Sonnenschutz - Farbe:
O ... Offen	A ... Aussen	M ... Mittel	W ... Weiss
G ... Geschlossen	ZW ... Zwischen	W ... Wenig	S ... Schwarz
K ... Gekippt	I ... Innen	S ... Stark	H ... Hell
N ... Nicht öffenbar	v7h ... vor 7:00 Uhr	E ... Eigene Angabe	D ... Dunkel

C.2. Summer Overheating KLG Hagedorn House 2

1

ArchiPHYSIK - A-NULL - SCHULVERSION

Beurteilung der Sommertauglichkeit

Bedroom 3 001

KLG Hagedorn House 2

Standort

1220 Wien-Donaustadt

Plangrundlagen

00.00.0000

Nutzung

Wohnung, Gästezimmer in Pensionen und Hotels

Verwendung eines Standard Raum-Nutzungsprofils aus ON B 8110-3

Annahmen zur Berechnung

Berechnungsgrundlage	ÖN B 8110-3:2012-03	**Hauptraum, detailliert**
Bauteile	EN ISO 6946:2003-10	
Fenster	EN ISO 10077-1:2006-12	
RLT	ON H 5057:2011-03-01	

Tag für die Berechnung des Nachweises

standard	15. Juli
Tagesmittelwert der Aussentemperatur	23,10 °C

Berechnungsvoraussetzung ist, dass keine wie immer gearteten Strömungsbehinderungen wie beispielsweise Insektenschutzgitter oder Vorhänge vorhanden sind. Zur Erreichung der erforderlichen Tag- und Nachtlüftung sind entsprechende Voraussetzungen für eine erhöhte natürliche Belüftung, wie öffenbare Fenster, erforderlichenfalls schalldämmende Lüftungseinrichtungen u. dgl., anzustreben. Zur Sicherstellung eines ausreichenden Luftaustausches bzw. einer ausreichenden Querlüftung zwischen den betrachtn Räumen sind entsprechende planerische Maßnahmen zur Einhaltung der erforderlichen Lüftungsquerschnitte zu setzen. Die Ermittlung selbst bezieht sich auf diesen einen Raum.

Operative Temperatur

min. operative Temperatur im Nachtzeitraum
(22:00 Uhr - 6:00 Uhr)

	22,07 °C
erforderlich:	27,00 °C
	19,91 °C
erforderlich:	25,00 °C

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020

Beurteilung der Sommertauglichkeit

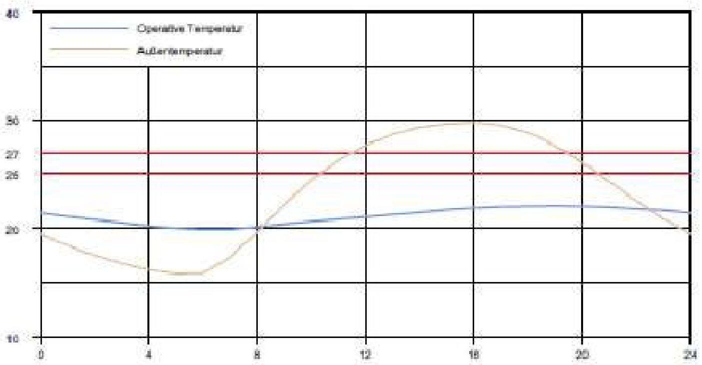
KLG Hagedorn House 2 - 001 - Bedroom 3

Immissionsflächenbezogene speicherwirksame Masse **9.507,10 kg/m²**

Immissionsfläche gesamt	0,24 m²
Fensterfläche	0,90 m²
Immisionsflächenbezogener stündlicher Luftvolumenstrom	141,08 m³/(h m²)
Speichermasse der Einrichtung/Ausstattung	38,00 kg/m²

Report

Tagesgang T a und operative Temperatur



h	T a °C	T op °C
0	19,51	21,40
1	18,38	21,10
2	17,47	20,80
3	16,73	20,50
4	16,17	20,23
5	15,82	20,03
6	15,96	19,91
7	17,27	19,92
8	19,61	20,16
9	22,14	20,40
10	24,43	20,62
11	26,28	20,84
12	27,68	21,04
13	28,67	21,25
14	29,30	21,46
15	29,65	21,71
16	29,74	21,88
17	29,50	21,99
18	28,80	22,04
19	27,62	22,07
20	26,06	22,04
21	24,29	21,93
22	22,51	21,80
23	20,89	21,66
24	19,51	21,40

Tagesmittelwert der Aussentemperatur **23,10 °C**

Lüftung und Raumlufttechnik

Raumlufttechnik

Fensterlüftung

Luftwechsel (Tag)	**0,40 1/h**
Luftwechsel (Nacht)	**1,50 1/h**
Luftwechsel bei Luftdichtigkeitsprüfung (n50)	**1,50 1/h**

Tagesgang Luftvolumenstrom nicht Standard

Raumgeometrie und Oberflächen

Bezugsfläche	Wohnnutzfläche	Netto-Raumvolumen	Fensteranteil
10,26 m2	**10,26 m2**	**22,57 m3**	**8,77 %**

Typ	Btl-Nr.	Bezeichnung	A m²	$m_{w,B,A}$ kg/m²	Speichermasse kg
ADh	R01	Roof	10,26	0,00	0,00
AF	W08	Window First Floor South	0,90	0,00	0,00

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020

3

Beurteilung der Sommertauglichkeit

KLG Hagedorn House 2 - 001 - Bedroom 3

Typ	Btl-Nr.	Bezeichnung	A m²	$m_{w,B,A}$ kg/m²	Speichermasse kg
AW	EW01	Exterior Wall	8,78	72,49	636,53
AW	EW01	Exterior Wall	3,76	72,49	272,88
AW	EW01	Exterior Wall	4,51	72,49	326,96
IDo	F03	Indoor slab	10,26	17,88	183,51
IW	IW02	Interior Wall 2	7,71	50,67	390,74
IW	IW03	Interior Wall 3	5,83	13,92	81,17
		Einrichtung	10,26	38,00	389,88
			Ø	**36,64**	**2.281,70**

Bauteile mit solarem Eintrag

Transp. Bauteile Süd, 0° (Z ON: 1,00)

Anzahl	Btl-Nr.	Bezeichnung	A_{AL} m²	f_G	Höhe m	Breite m	Öff/Kippw. m	g-Wert	F_{Sc}	F_C
1x	W08	Window First Floor South	0,90	0,70	1,00	0,90	O	0,61	1,00	0,62

Verschattung und Sonnenschutz

Transp. Bauteile Süd, 0°

Btl-Nr.	Bezeichnung	Transmission/Reflexion $\tau_{e,B}$	$\rho_{e,B}$	ε	Sonnenschutz Lage	Lichtdl.	Farbe	v7h	Verschattung Fh	Fo	Ff
W08	Window First Floor South	0,20	0,60	0,00	I	M	W	nein	1,00	1,00	1,00

Legende zu den Tabellen der transp. Bauteile

Öffnungstyp:	Sonnenschutz - Lage:	Sonnenschutz - Lichtdurchlass:	Sonnenschutz - Farbe:
O ... Offen	A ... Aussen	M ... Mittel	W ... Weiss
G ... Geschlossen	ZW ... Zwischen	W ... Wenig	S ... Schwarz
K ... Gekippt	I ... Innen	S ... Stark	H ... Hell
N ... Nicht öffenbar	v7h ... vor 7:00 Uhr	E ... Eigene Angabe	D ... Dunkel

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020

C.3. Summer Overheating KLG Hagedorn House 3

1

ArchiPHYSIK - A-NULL - SCHULVERSION

Beurteilung der Sommertauglichkeit

Bedroom air conditioned 001

KLG Hagedorn House 3

Standort

1220 Wien-Donaustadt

Plangrundlagen

00.00.0000

Nutzung

Wohnung, Gästezimmer in Pensionen und Hotels

Verwendung eines Standard Raum-Nutzungsprofils aus ON B 8110-3

Annahmen zur Berechnung

Berechnungsgrundlage	ÖN B 8110-3:2012-03	**Hauptraum, detailliert**
Bauteile	EN ISO 6946:2003-10	
Fenster	EN ISO 10077-1:2006-12	
RLT	ON H 5057:2011-03-01	

Tag für die Berechnung des Nachweises

standard	15. Juli
Tagesmittelwert der Aussentemperatur	23,10 °C

Berechnungsvoraussetzung ist, dass keine wie immer gearteten Strömungsbehinderungen wie beispielsweise Insektenschutzgitter oder Vorhänge vorhanden sind. Zur Erreichung der erforderlichen Tag- und Nachtlüftung sind entsprechende Voraussetzungen für eine erhöhte natürliche Belüftung, wie öffenbare Fenster, erforderlichenfalls schalldämmende Lüftungseinrichtungen u. dgl., anzustreben. Zur Sicherstellung eines ausreichenden Luftaustausches bzw. einer ausreichenden Querlüftung zwischen den betrachtn Räumen sind entsprechende planerische Maßnahmen zur Einhaltung der erforderlichen Lüftungsquerschnitte zu setzen. Die Ermittlung selbst bezieht sich auf diesen einen Raum.

Operative Temperatur

Operative Temperatur		**23,85 °C**
	erforderlich:	27,00 °C
min. operative Temperatur im Nachtzeitraum (22:00 Uhr - 6:00 Uhr)		**20,81 °C**
	erforderlich:	25,00 °C

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020

Beurteilung der Sommertauglichkeit

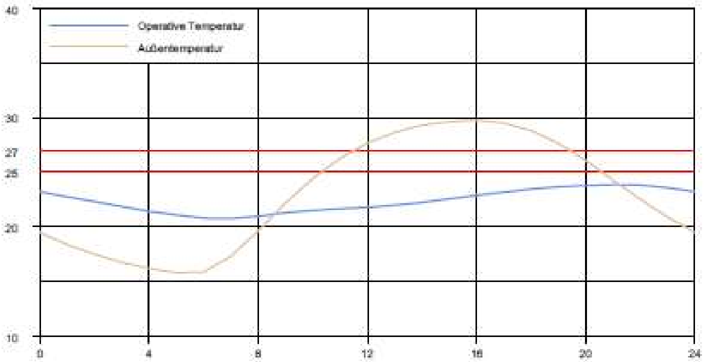
KLG Hagedorn House 3 - 001 - Bedroom air conditioned

Immissionsflächenbezogene speicherwirksame Masse — 45.641,99 kg/m²

Immissionsfläche gesamt	0,09	m²
Fensterfläche	2,10	m²
Immisionsflächenbezogener stündlicher Luftvolumenstrom	667,29	m³/(h m²)
Speichermasse der Einrichtung/Ausstattung	38,00	kg/m²

Report

Tagesgang T a und operative Temperatur



h	T a °C	T op °C
0	19,51	23,20
1	18,38	22,76
2	17,47	22,31
3	16,73	21,86
4	16,17	21,43
5	15,82	21,08
6	15,86	20,81
7	17,27	20,76
8	19,61	20,98
9	22,14	21,27
10	24,43	21,48
11	26,28	21,64
12	27,68	21,79
13	28,67	21,97
14	29,30	22,22
15	29,65	22,56
16	29,74	22,88
17	29,50	23,18
18	28,80	23,44
19	27,62	23,65
20	26,06	23,79
21	24,29	23,85
22	22,51	23,82
23	20,89	23,58
24	19,51	23,20

Tagesmittelwert der Aussentemperatur **23,10 °C**

Lüftung und Raumlufttechnik

Raumlufttechnik

Fensterlüftung

Luftwechsel (Tag)	**0,40**	**1/h**
Luftwechsel (Nacht)	**1,50**	**1/h**
Luftwechsel bei Luftdichtigkeitsprüfung (n50)	**1,50**	**1/h**

Tagesgang Luftvolumenstrom nicht Standard

Raumgeometrie und Oberflächen

Bezugsfläche	Wohnnutzfläche	Netto-Raumvolumen	Fensteranteil
17,11 m2	**17,11 m2**	**40,03 m3**	**12,27 %**

Typ	Btl-Nr.	Bezeichnung	A m²	$m_{w,B,A}$ kg/m²	Speichermasse kg
ADh	R01	Roof	17,11	45,60	780,21
AF	W03	Window First Floor South	0,90	0,00	0,00

Beurteilung der Sommertauglichkeit

KLG Hagedorn House 3 - 001 - Bedroom air conditioned

Typ	Btl-Nr.	Bezeichnung	A m²	$m_{w,B,A}$ kg/m²	Speichermasse kg
AF	W04	Window First Floor West	1,20	0,00	0,00
AW	EW01	Exterior Wall	8,25	60,23	496,94
AW	EW01	Exterior Wall	8,25	60,23	496,94
AW	EW01	Exterior Wall	13,49	60,23	812,63
IDo	F02	Indoor slab	17,11	8,27	141,66
IW	IW02	Interior Wall 2	14,39	50,67	729,19
		Einrichtung	17,11	38,00	650,18
			Ø	**42,00**	**4.107,78**

Bauteile mit solarem Eintrag

Transp. Bauteile Süd, 0° (Z ON: 1,00)

Anzahl	Btl-Nr.	Bezeichnung	A_{AL} m²	f_G	Höhe m	Breite m	Öff/Kippw. m	g-Wert	F_{Sc}	F_c
1x	W03	Window First Floor South	0,90	0,70	0,90	1,00	O	0,55	1,00	0,10

Transp. Bauteile West, 0° (Z ON: 1,13)

Anzahl	Btl-Nr.	Bezeichnung	A_{AL} m²	f_G	Höhe m	Breite m	Öff/Kippw. m	g-Wert	F_{Sc}	F_c
1x	W04	Window First Floor West	1,20	0,70	1,00	1,20	O	0,55	1,00	0,10

Verschattung und Sonnenschutz

Transp. Bauteile Süd, 0°

Btl-Nr.	Bezeichnung	Transmission/Reflexion $\tau_{e,B}$	$\rho_{e,B}$	ε	Sonnenschutz Lage	Lichtdl.	Farbe	v7h	Verschattung Fh	Fo	Ff
W03	Window First Floor South	0,05	0,70	2,50	A	W	W	ja	1,00	1,00	1,00

Transp. Bauteile West, 0°

Btl-Nr.	Bezeichnung	Transmission/Reflexion $\tau_{e,B}$	$\rho_{e,B}$	ε	Sonnenschutz Lage	Lichtdl.	Farbe	v7h	Verschattung Fh	Fo	Ff
W04	Window First Floor West	0,05	0,70	2,50	A	W	W	ja	1,00	1,00	1,00

Legende zu den Tabellen der transp. Bauteile

Öffnungstyp:	Sonnenschutz - Lage:	Sonnenschutz - Lichtdurchlass:	Sonnenschutz - Farbe:
O ... Offen	A ... Aussen	M ... Mittel	W ... Weiss
G ... Geschlossen	ZW ... Zwischen	W ... Wenig	S ... Schwarz
K ... Gekippt	I ... Innen	S ... Stark	H ... Hell
N ... Nicht öffenbar	v7h ... vor 7:00 Uhr	E ... Eigene Angabe	D ... Dunkel

C.4. Summer Overheating KLG Eschenkogel

1

ArchiPHYSIK - A-NULL - SCHULVERSION

Beurteilung der Sommertauglichkeit

Bedroom 2 001

KLG Eschenkogel

Standort

1100 Wien-Favoriten

Plangrundlagen

00.00.0000

Nutzung

Wohnung, Gästezimmer in Pensionen und Hotels

Verwendung eines Standard Raum-Nutzungsprofils aus ON B 8110-3

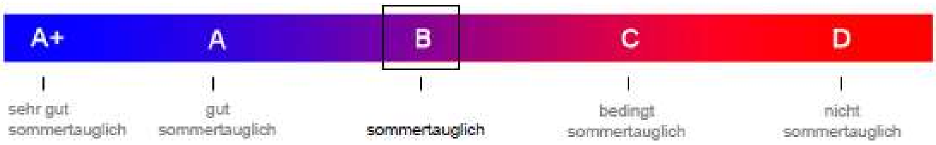
Annahmen zur Berechnung

Berechnungsgrundlage	ÖN B 8110-3:2012-03	**Hauptraum, detailliert**
Bauteile	EN ISO 6946:2003-10	
Fenster	EN ISO 10077-1:2006-12	
RLT	ON H 5057:2011-03-01	

Tag für die Berechnung des Nachweises

standard	15. Juli
Tagesmittelwert der Aussentemperatur	23,60 °C

Berechnungsvoraussetzung ist, dass keine wie immer gearteten Strömungsbehinderungen wie beispielsweise Insektenschutzgitter oder Vorhänge vorhanden sind. Zur Erreichung der erforderlichen Tag- und Nachtlüftung sind entsprechende Voraussetzungen für eine erhöhte natürliche Belüftung, wie öffenbare Fenster, erforderlichenfalls schalldämmende Lüftungseinrichtungen u. dgl., anzustreben. Zur Sicherstellung eines ausreichenden Luftaustausches bzw. einer ausreichenden Querlüftung zwischen den betrachtn Räumen sind entsprechende planerische Maßnahmen zur Einhaltung der erforderlichen Lüftungsquerschnitte zu setzen. Die Ermittlung selbst bezieht sich auf diesen einen Raum.



Operative Temperatur — **26,28 °C** (erforderlich: 27,00 °C)

min. operative Temperatur im Nachtzeitraum (22:00 Uhr - 6:00 Uhr) — **23,72 °C** (erforderlich: 25,00 °C)

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020

Beurteilung der Sommertauglichkeit

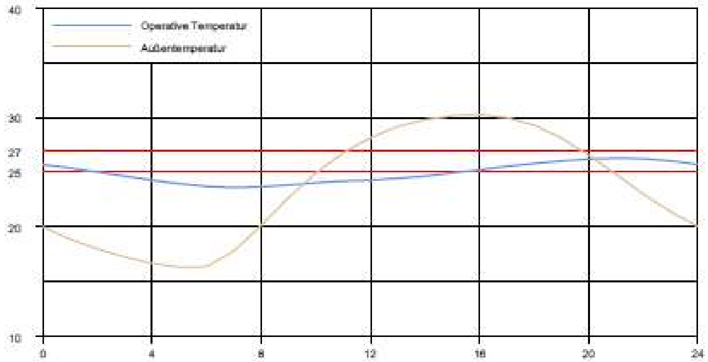
KLG Eschenkogel - 001 - Bedroom 2

Immissionsflächenbezogene speicherwirksame Masse **6.541,04 kg/m²**

Immissionsfläche gesamt	0,38	m²
Fensterfläche	0,90	m²
Immisionsflächenbezogener stündlicher Luftvolumenstrom	103,08	m³/(h m²)
Speichermasse der Einrichtung/Ausstattung	38,00	kg/m²

Report

Tagesgang T a und operative Temperatur



h	T a °C	T op °C
0	20,01	25,72
1	18,88	25,38
2	17,97	25,01
3	17,23	24,63
4	16,67	24,26
5	16,32	23,95
6	16,36	23,72
7	17,77	23,59
8	20,11	23,65
9	22,64	23,83
10	24,93	24,04
11	26,78	24,18
12	28,18	24,29
13	29,17	24,43
14	29,80	24,63
15	30,15	24,92
16	30,24	25,22
17	30,00	25,53
18	29,30	25,80
19	28,12	26,04
20	26,56	26,21
21	24,79	26,28
22	23,01	26,22
23	21,39	26,02
24	20,01	25,72

Tagesmittelwert der Aussentemperatur **23,60 °C**

Lüftung und Raumlufttechnik

Raumlufttechnik

Fensterlüftung

Luftwechsel (Tag)	**0,40**	**1/h**
Luftwechsel (Nacht)	**1,50**	**1/h**
Luftwechsel bei Luftdichtigkeitsprüfung (n50)	**1,50**	**1/h**

Tagesgang Luftvolumenstrom nicht Standard

Raumgeometrie und Oberflächen

Bezugsfläche	Wohnnutzfläche	Netto-Raumvolumen	Fensteranteil
14,66 m2	**14,66 m2**	**26,11 m3**	**6,14 %**

Typ	Btl-Nr.	Bezeichnung	A m²	$m_{w,B,A}$ kg/m²	Speichermasse kg
ADh	R01	Roof	21,78	47,70	1.039,09
AF	W05	Window First Floor South	0,45	0,00	0,00

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020

Beurteilung der Sommertauglichkeit

KLG Eschenkogel - 001 - Bedroom 2

Typ	Btl-Nr.	Bezeichnung	A m²	$m_{w,B,A}$ kg/m²	Speichermasse kg
AF	W05	Window First Floor South	0,45	0,00	0,00
AW	EW01	Exterior Wall annex + old ones renovated	1,72	47,70	82,28
AW	EW01	Exterior Wall annex + old ones renovated	5,00	47,70	238,50
AW	EW01	Exterior Wall annex + old ones renovated	1,55	66,50	103,14
IDo	F03	Indoor slab	14,66	17,88	262,21
IW	IW01	Interior Wall	9,37	13,92	130,53
IW	IW01	Interior Wall	2,47	13,92	34,46
IW	IW01	Interior Wall	2,75	13,92	38,28
		Einrichtung	14,66	38,00	557,08
			Ø	**33,19**	**2.485,60**

Bauteile mit solarem Eintrag

Transp. Bauteile Süd, 0° (Z ON: 1,00)

Anzahl	Btl-Nr.	Bezeichnung	A_{AL} m²	f_G	Höhe m	Breite m	Öff/Kippw. m	g-Wert	F_{Sc}	F_c
1x	W05	Window First Floor South	0,45	0,70	0,50	0,90	O	0,61	1,00	1,00
1x	W05	Window First Floor South	0,45	0,70	0,50	0,90	O	0,61	1,00	1,00

Verschattung und Sonnenschutz

Transp. Bauteile Süd, 0°

		Transmission/Reflexion			Sonnenschutz				Verschattung		
Btl-Nr.	Bezeichnung	$\tau_{e,B}$	$\rho_{e,B}$	ε	Lage	Lichtdl.	Farbe	v7h	Fh	Fo	Ff
W05	Window First Floor South	0,05	0,70	0,00	-	-	-	nein	1,00	1,00	1,00
W05	Window First Floor South	0,05	0,70	0,00	-	-	-	nein	1,00	1,00	1,00

Legende zu den Tabellen der transp. Bauteile

Öffnungstyp:
O ... Offen
G ... Geschlossen
K ... Gekippt
N ... Nicht öffenbar

Sonnenschutz - Lage:
A ... Aussen
ZW ... Zwischen
I ... Innen
v7h ... vor 7:00 Uhr

Sonnenschutz - Lichtdurchlass:
M ... Mittel
W ... Wenig
S ... Stark
E ... Eigene Angabe

Sonnenschutz - Farbe:
W ... Weiss
S ... Schwarz
H ... Hell
D ... Dunkel

C.5. Summer Overheating Temporary KLG Klagergrube

1

ArchiPHYSIK - A-NULL - SCHULVERSION

Beurteilung der Sommertauglichkeit

Living room 001

Temporary KLG Klagergrube

Standort

1220 Wien-Donaustadt

Plangrundlagen

00.00.0000

Nutzung

Wohnung, Gästezimmer in Pensionen und Hotels

Verwendung eines Standard Raum-Nutzungsprofils aus ON B 8110-3

Annahmen zur Berechnung

Berechnungsgrundlage	ÖN B 8110-3:2012-03	**Hauptraum, detailliert**
Bauteile	EN ISO 6946:2003-10	
Fenster	EN ISO 10077-1:2006-12	
RLT	ON H 5057:2011-03-01	

Tag für die Berechnung des Nachweises

standard	15. Juli
Tagesmittelwert der Aussentemperatur	23,10 °C

Berechnungsvoraussetzung ist, dass keine wie immer gearteten Strömungsbehinderungen wie beispielsweise Insektenschutzgitter oder Vorhänge vorhanden sind. Zur Erreichung der erforderlichen Tag- und Nachtlüftung sind entsprechende Voraussetzungen für eine erhöhte natürliche Belüftung, wie öffenbare Fenster, erforderlichenfalls schalldämmende Lüftungseinrichtungen u. dgl., anzustreben. Zur Sicherstellung eines ausreichenden Luftaustausches bzw. einer ausreichenden Querlüftung zwischen den betrachtn Räumen sind entsprechende planerische Maßnahmen zur Einhaltung der erforderlichen Lüftungsquerschnitte zu setzen. Die Ermittlung selbst bezieht sich auf diesen einen Raum.

Operative Temperatur		**22,86 °C**
	erforderlich:	27,00 °C
min. operative Temperatur im Nachtzeitraum (22:00 Uhr - 6:00 Uhr)		**20,01 °C**
	erforderlich:	25,00 °C

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020

Beurteilung der Sommertauglichkeit

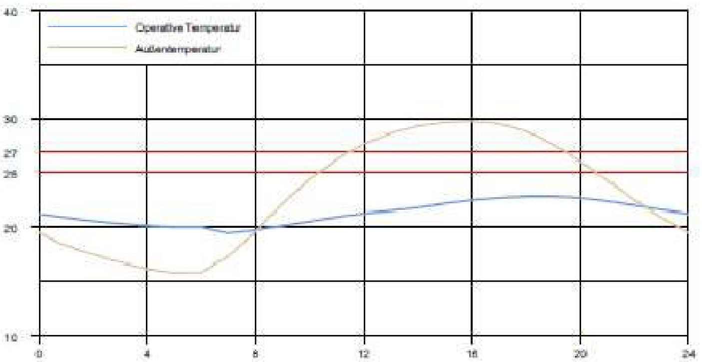
Temporary KLG Klagergrube - 001 - Living room

Immissionsflächenbezogene speicherwirksame Masse — 0,00 kg/m²

Immissionsfläche gesamt	0,00 m²
Fensterfläche	1,91 m²
Immisionsflächenbezogener stündlicher Luftvolumenstrom	0,00 m³/(h m²)
Speichermasse der Einrichtung/Ausstattung	38,00 kg/m²

Report

Tagesgang T a und operative Temperatur



h	Ta °C	Top °C
0	19,51	21,25
1	18,38	20,91
2	17,47	20,61
3	16,73	20,36
4	16,17	20,15
5	15,82	20,03
6	15,86	20,01
7	17,27	19,44
8	19,61	19,73
9	22,14	20,14
10	24,43	20,56
11	26,28	20,95
12	27,68	21,27
13	28,67	21,55
14	29,30	21,84
15	29,65	22,20
16	29,74	22,51
17	29,58	22,74
18	28,80	22,85
19	27,62	22,86
20	26,06	22,71
21	24,29	22,41
22	22,51	22,02
23	20,89	21,63
24	19,51	21,25

Tagesmittelwert der Aussentemperatur **23,10 °C**

Lüftung und Raumlufttechnik

Raumlufttechnik

Fensterlüftung

Luftwechsel (Tag)	**0,40 1/h**
Luftwechsel (Nacht)	**1,50 1/h**
Luftwechsel bei Luftdichtigkeitsprüfung (n50)	**1,50 1/h**

Tagesgang Luftvolumenstrom nicht Standard

Raumgeometrie und Oberflächen

Bezugsfläche	Wohnnutzfläche	Netto-Raumvolumen	Fensteranteil
13,33 m2	**13,33 m2**	**27,95 m3**	**14,33 %**

Typ	Btl-Nr.	Bezeichnung	A m²	$m_{w,I,A}$ kg/m²	Speichermasse kg
AD	R01	Roof	13,32	0,00	0,00
AF	W01	Window	0,48	0,00	0,00

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020

3

Beurteilung der Sommertauglichkeit

Temporary KLG Klagergrube - 001 - Living room

Typ	Btl-Nr.	Bezeichnung	A m²	$m_{w,B,A}$ kg/m²	Speichermasse kg
AT	T01	Door	1,43	0,00	0,00
AW	EW01	Exterior Wall	8,34	11,50	95,91
AW	EW01	Exterior Wall	10,25	11,50	117,87
AW	EW01	Exterior Wall	8,12	11,50	93,43
AW	EW01	Exterior Wall	8,12	11,50	93,43
EBu	F01	Floor to ground	13,32	11,50	153,23
		Einrichtung	13,33	38,00	506,54
			Ø	**13,82**	**1.060,44**

Bauteile mit solarem Eintrag

Transp. Bauteile Nord, 0° (Z ON: 0,00)

Anzahl	Btl-Nr.	Bezeichnung	A_{AL} m²	f_G	Höhe m	Breite m	Öff/Kippw. m	g-Wert	F_{SC}	F_C
1x	W01	Window	0,48	0,70	0,60	0,80	G	0,71	1,00	0,21
1x	T01	Door	1,43	0,70	1,90	0,75	G	0,00	1,00	0,00

Verschattung und Sonnenschutz

Transp. Bauteile Nord, 0°

		Transmission/Reflexion			Sonnenschutz				Verschattung		
Btl-Nr.	Bezeichnung	$\tau_{e,B}$	$\rho_{e,B}$	ε	Lage	Lichtdl.	Farbe	v7h	Fh	Fo	Ff
W01	Window	0,05	0,30	0,00	A	W	D	ja	1,00	1,00	1,00
T01	Door	0,05	0,30	0,00	A	W	D	nein	1,00	1,00	1,00

Legende zu den Tabellen der transp. Bauteile

Öffnungstyp:
O ... Offen
G ... Geschlossen
K ... Gekippt
N ... Nicht öffenbar

Sonnenschutz - Lage:
A ... Aussen
ZW ... Zwischen
I ... Innen
v7h ... vor 7:00 Uhr

Sonnenschutz - Lichtdurchlass:
M ... Mittel
W ... Wenig
S ... Stark
E ... Eigene Angabe

Sonnenschutz - Farbe:
W ... Weiss
S ... Schwarz
H ... Hell
D ... Dunkel

ArchiPHYSIK - A-NULL - SCHULVERSION Educ. 29.10.2020