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Retrofit versus New Construction; A Life-Cycle-Assessment (LCA) Case Study of Single Family Houses in Lower Austria

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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

Tanja Schmidt, BSc

Matrikelnr. 01526716

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KURZFASSUNG

Gebäude tragen in hohem Maße zum globalen Treibhausgasausstoß und Energieverbrauch bei. Um festzustellen, wie umweltverträglich ein Gebäude oder auch ein Baumaterial tatsächlich ist, muss dessen gesamter Lebenszyklus betrachtet werden. Eine Lebenszyklusanalyse kann dazu beitragen, Verbesserungen der Umwelteigenschaften von Produkten in den verschiedenen Phasen ihres Lebenszyklus aufzuzeigen. Die facheinschlägige Normung schlägt dafür Methoden und Werkzeuge vor. Viele Studien befassen sich mit Neubauten und sehr effizienten Gebäuden. Die Potentiale von bestehenden Gebäuden werden meist vernachlässigt. Zu den Potentialen zählt unter anderem, dass bei bestehenden Gebäuden bereits eine Bausubstanz vorhanden ist und diese oft nur umgenutzt, adaptiert oder saniert werden muss, während bei Neubauten meist noch unversiegelte Flächen bebaut werden. Dies hat einen positiven Einfluss auf die globale Erderwärmung.

Oft steht man jedoch vor der Frage, wie mit einem bestehenden Gebäude verfahren werden soll. Die vorliegende Masterarbeit beschäftigt sich daher mit der Frage, ob verschiedene Sanierungsvarianten einem Neubau im Hinblick auf deren ökologische Performance vorzuziehen sind - auf Basis zweier bestehender Einfamilienhäuser in Langenlois (Niederösterreich) verglichen mit einem fiktiven Neubau.

Ziel dieser Studie ist es, verschiedene Renovierungsmaßnahmen an den zwei bestehenden Gebäuden unterschiedlichen Alters durchzuführen. Die daraus resultierenden Ergebnisse werden dann mit jenen des fiktiven Neubaus verglichen. Um zu einem Ergebnis der gestellten Forschungsfrage zu gelangen, werden die verschiedenen Renovierungsszenarien wie folgt mit dem Neubau verglichen: Der fiktive Neubau wird 2020 errichtet. Die Sanierungsmaßnahmen der bestehenden Gebäude werden ebenfalls im Jahr 2020 durchgeführt. Von diesem Zeitpunkt aus wird mit einer Lebensdauer von 50 Jahren gerechnet.

Die Studie befasst sich in erster Linie mit den verwendeten Materialien und nicht mit unterschiedlichen Heizoptionen. Die Art der Beheizung ist für alle durchgeführten Szenarien gleich. In den Ergebnissen wird zwischen Umweltauswirkungen der Investitionsmaßnahmen sowie deren, die durch das Beheizen der Gebäude entsteht, unterschieden.

Stichwörter

Life-Cycle-Assessment, Umwelteinwirkungen, Nachhaltigkeit, bestehende Gebäude, Einfamilienhäuser, vergleichende Betrachtung , Fallstudie

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ABSTRACT

Buildings are a major contributor to greenhouse gases and energy consumption. In order to determine how ecological a building or building material really is, its entire life cycle must be considered. A life cycle assessment can help to show improvements in the environmental properties of products in the various phases of their life-cycle. (Facheinschlägige Normung) Many research studies deal with new constructions and very efficient buildings. The potentials of existing buildings are mostly neglected. Potentials include, among other things, that existing buildings already have a building substance and that this often only has to be reused, adapted or renovated, while new buildings usually are built on unsealed areas. This has a positive impact on global warming.

However, one is often faced with the question of how to proceed with an existing building. Therefore, this master's thesis deals with the question of whether various renovation options are preferable to a new building from an ecological point of view, based on two existing and one yet-to-be-built case study buildings in Langenlois, Lower Austria.

The objective of this study is to gain insights into the performance of different strategies regarding building retrofit in comparison to the performance of a newly-built building. Thereby, different retrofit measures are virtually applied to the two existing buildings. Performance indicators that have been derived from these efforts include heating demand and environmental footprint. The results of each case study building are then compared and analyzed. In order to arrive at a result of the research question posed, the various renovation scenarios are compared with the new building as follows: The fictitious new building will be built in 2020. The retrofit measures of the existing buildings will also be carried out in 2020. From this point in time, a service life of 50 years is expected.

This study majorly focusses on the material-related environmental footprint. Operational energy demand of the buildings is considered; however, the same heating system settings have been assumed for each of the case study buildings. The results distinguish between the environmental effects of the investment measures and those resulting from the heating of the buildings.

Keywords

Life-Cycle-Assessment, Environmental impact, sustainability, existing buildings, single-family houses, comparative analysis, Case Study

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Many thanks to my parents and my grandmother for giving me the possibility to use their houses as case studies for this thesis.

Above all, I would like to express my sincere gratitude to my whole family and my friends for their continuous support not only during the process of writing this thesis but throughout my entire life.

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1 INTRODUCTION

1.1 Overview

Buildings account for more than 40% of the global energy consumption. Of this 40% residential buildings are considered to be responsible for 75% of them and commercial buildings for 25%. Moreover, buildings are responsible for up to one third of global greenhouse gas emissions. This applies to both developed and developing countries (Huovila et al. 2019), (Lucon et al. 2014). These values impressively show that buildings have a significant and mostly harmful impact on our environment. It is common understanding that mankind urgently needs to decrease these effects of the built environment onto the overall environment. As such, the building sector can be considered to have a key role in any policy regarding lowering GHG-emissions and energy consumption, given its share is larger than those of transport and industry.

Given the low rates of new building construction (Bigalke et al. 2016), it seems obvious that both new buildings and the existing building stock need to be addressed. While the performance of new buildings can be pre-determined by adopting the building codes regarding thermal quality and defining threshold values for KPIs (Key performance indicators) of new buildings, the reduction of energy consumption and emissions of the existing building stock is not that easy.

To better understand the performance of existing buildings in contrast and comparison to new buildings, it seems useful to examine the performance of building retrofit and new buildings in a holistic and multi-criterial fashion. Such studies – as the present thesis is encompassing one – might provide new insights for decision-making for retrofit or demolish-and-build-new cases. Needless to say, aside from environmentally-related objectives, the cost of measures is an important aspect that needs to be considered as well.

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1.2 Motivation

As already mentioned, the built environment is responsible for a major share of the global energy consumption. Given that the majority of buildings are residential buildings, it is important to look at this type of buildings in detail. The results of a register-based census of 2011 have shown that nine out of ten buildings in Austria are used for residential purposes. Lower Austria has the highest proportion of buildings (Asamer et al. 2011).

This master thesis presents the approach, methodology, and results of a case study. This case study examines – beside an envisioned, new building - two existing buildings in Langenlois, a town in Lower Austria. Langenlois has a diverse portfolio of existing buildings, but the majority of buildings have been built before 1919, followed by buildings erected between 1961 and 1991, and buildings constructed from 1991 onwards.

Table 1 shows an overview about the age of the building stock (as taken from the census of 2011). (NOE n.d.)

Table 1: Share of buildings by % (source: illustration by the author)

Share of buildings by % in construction periods in Langenlois	
	Census 2011 [%]
built before 1919	30.48
built 1919 - 1944	5.57
built 1945 - 1960	6.88
built 1961 - 1990	29.9
built from 1991 onwards	27.17

One of the two case study single-family houses selected for this study was constructed before 1919, while the other one belongs to the period between 1961 and 1990.

In Langenlois, as in many other (Austrian) towns and villages, the problem of urban sprawl is becoming increasingly acute. This means that new buildings are erected on the outskirts of the city.

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There is a set of negative consequences connected with that sprawl: These are for instance, to name a few, increased abandonment of city centers, increased dependency on motorized traffic, high infrastructure cost, and loss of identity of the village. In the case of Langenlois, the city's identity and vibrant center is of high importance due to touristic reasons. The town is an over-regional center of viticulture and is well known for the wine taverns located in the village (Heurigen) (Cerveny et al. 2011), (Lindner et al. 2014).

Another aspect that needs to be considered is, that urban sprawl (and the connected construction of new buildings outside of city centers and the connected infrastructure) further increases the tendency of sealed land surfaces. Surface sealing is known to increase environmental issues such as global warming, probability of flooding, threat to biodiversity, threat to food security, threat to global carbon cycle and reduced air quality. In this context it should be mentioned that Austria is currently considered as one of the countries with the highest per day sealing rate in Europe and worldwide (Umweltbundesamt n.d.).

It can be observed that many people today consider low impact on the environment and reduced energy consumption as an equally important aspect for buildings as investment and operation cost. However, the general opinion is that retrofitted existing/old buildings cannot achieve the same level of performance regarding thermal insulation and energy savings as new, highly efficient buildings. This master thesis has been conducted with the goal to investigate if different renovation measures of existing buildings can compete with new buildings in view of performative, ecological and economic criteria.

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1.3 Background

To the knowledge of the author, there have been some recent studies published, which focus on a comparison of the performance of improved existing buildings and new buildings. The contributions mentioned in the next paragraphs have not to be understood as taxative list of these contributions, but rather as exemplary instances of such studies.

For instance, Marique and Rossi (2018) published an article named “Cradle-to-grave life-cycle assessment within the built environment: Comparison between refurbishment and the complete reconstruction of an office building in Belgium”. Their main objective was to update an existing tool for life-cycle assessment and then apply it to a case study. The retrofitted building was compared with the complete demolition and reconstruction through two environmental impacts – the global warming potential and the energy consumption. This study in Belgium showed, that the renovated building was significantly less harmful than its demolition and reconstruction. Furthermore, the study found that the use phase for both cases was the most harmful phase. (Marique et al. 2018)

Many studies have been conducted in a different climatic context, for instance subtropical climates. Blengini (2009) published a study in which demolition and recycling potential was investigated on the basis of a single-family house in Torino (classified as subtropic climate following the Köppen classification). The study was embedded in the context of urban sprawl. As such, the effort required for demolition of existing buildings was not included in the study. Rather, the new building was envisioned (and constructed) on a yet unoccupied building site. Also this research showed that the environmental impact of the use phase for this kind of buildings was the most important one. The environmental benefits from the end-of-life phase were compared to the full life cycle impacts. This comparison has shown that the environmental benefits for the used conventional building was relatively small. (Blengini 2009) In the present master thesis the recycling potential was neglected.

In 2016, a master thesis on the mentioned subject has been published at the Technical University. This work deals with the problem of unused farmhouses in Burgenland (Austria). First and foremost, the focus is on thermal improvement and cost analysis of the measures taken. This master thesis showed that building a new house is more expensive than a simple renovation or extension of a building – at least in this case study. (Padayhag 2015) In contrast, the present master thesis focuses more on the ecological aspects and the environmental impact of the planned investigations.

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1.4 Hypothesis

As already mentioned, a set of previous research efforts have been carried out. These in general underlined that regularly the renovation of existing structures shows advantages in comparison to new buildings in view of environmental and performative aspects. Most of these studies included the demolition of an existing building as preface to the new building's construction. This is not the case in the present case study. The envisioned new building will be constructed on a not-yet-occupied building site close to the existing structures.

Previous studies have shown that the results of enquiries comparable to those addressed in this contribution are strongly influenced by the evaluated time span. Thereby it can be stated that highly-energy-efficient buildings regularly show the best performance in studies that consider a very long evaluation time span.

Key performance parameters examined in this master thesis include the energy demand of the buildings for heating (heating demand). Thereby, existing data, taken from electricity and gas supply companies in form of invoices that state the usage of electricity and gas is used (existing buildings) as well as state-of-the art normative calculation methods (existing buildings, new building). Different retrofit scenarios are created and compared.

Given the multitude of sources for the calculations and comparison of the performance (e.g. coming from plans, energy bills, assumptions about the thermal quality of the buildings, etc.) it is not trivial to compare the performance of the existing buildings and potential retrofit routines with the yet-to-be-built new building.

The major research questions are:

1. Which methodical steps are required to perform a holistic comparison between existing buildings (in their original shape and potential retrofit scenarios) with a yet-to-be-built building.
2. Can the findings of other studies regarding the better performance of retrofit of existing buildings in contrast to the performance of new buildings be confirmed based on this case study?

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2 METHOD

2.1 Overview

The starting point of this master thesis are two existing residential buildings in Langenlois (Lower Austria). These two buildings were selected based on the most common building époques that can be found in this town (see Introduction section).

The older building ("A") was originally built before 1890. The exact date is neither known by the owners nor by governmental records. This building consists of a heated ground floor and an unheated attic space. The heated gross area is 129.19 m².

The other building ("B") was constructed in 1990. Similar to the first building only the ground floor is heated. In addition to the ground floor and unheated attic space this house has an unheated basement. In this building the heated gross area is 150.42 m².

Both buildings are constructed of solid masonry. This construction method was the most commonly used in this region. The two buildings are adjacent to each other, separated by a courtyard. For both buildings three different retrofit scenarios will be considered. Two of them are relatively inexpensive and are carried out frequently. These measures will demonstrate the extent to which such small changes already have an impact on the performance of the buildings and thus on the environment. The first developed measure is the replacement of the current windows by new insulation-glass windows. In the second refurbishment scenario, the walls and the ceiling of both buildings will be improved with (additional) thermal insulation. In a third renovation option, the buildings are significantly improved to low-energy standards. These different retrofit scenarios are compared with a fictitious new building ("C").

This new building is envisioned to be constructed of solid brickwork and implements low energy standards. For a better comparability to one of the two existing buildings, the building was assumed to be of similar heated gross area and shape as the 1990 building.

A detailed description of the different evaluated scenarios (Status Quo and different retrofit scenarios) can be found in the Scenario (Sub-)section.

In order to arrive at results that allow answering the research questions, the various renovation scenarios are compared with the new construction as follows: The fictitious new building is assumed to be constructed in 2020. The refurbishment variants of the existing buildings are also assumed to be carried out in 2020. From this point in time, a life span of 50 years is expected for the new building and the two existing buildings.

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2.1.1 Calculation of environmental impact

To assess the environmental impact of newly added materials and demolished materials, values are determined based on the OI3 indicators (IBO 2018). This indicator system, which is a simplification of more advanced standardized evaluation systems, as for instance suggested in EN ISO 14040 (ÖNORM EN ISO 14040), is based on part indicators for Global Warming Potential (GWP), Acidification (AP), and the demand for non-renewable energy resources (PEI n.e.):

Global Warming Potential (GWP), CO_2-equivalents:

The Global Warming Potential describes the contribution of a trace gas to global warming. Global warming therefore refers to the increase of atmospheric temperature. The indicator "GWP sum", which is used for the eco-indicator OI3, account both the contribution of greenhouse gas emissions to global warming and the amount of carbon dioxide stored in biomass. Greenhouse potential such as carbon dioxide (CO_2), methane (CH_4), fluorocarbons (HFCs) are the biggest contributors to global warming. (IBO n.d.)

In this paper the Global Warming Potential is given in kilogram CO_2-equivalents per square-meter and as absolute values in kilograms CO_2-equivalents.

Acidification (AP), SO_2-equivalents:

Acidification is mainly caused by the interaction of nitrogen oxide (NOX) and Sulphur dioxide (SO_2) gases with other air constituents. Among the clearly assigned consequences is the acidification of lakes and water bodies. This leads to a decimation of fish stocks in number and diversity. Acidification can also affect trees, soil, animals and humans. The average "European acidification potential" is used to calculate the acidification potential (AP). In this work the Acidification Potential is given in kilogram SO_2-equivalents per square-meter and as absolute values in kilogram SO_2-equivalents.

Demand for non-renewable energy resource (PEI n.e.):

For the eco-indicator OI3 the primary energy content of all non-renewable resources (oil, coal, etc.) consumed for the production process is used. The primary energy content is calculated from the lower calorific value of all energy-containing resources used. This category is expressed in MJ.

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The ΔOI3 points per m² resulting for the respective component layers which were removed or added were calculated with Equation 1 (based on IBO 2018):

$$\Delta OI3 = 1/3 * [1/10 * (PEI\ n.e.) + 1/2 * (GWP) + 100/0{,}25 * (AP)] \quad (1)$$

(PEI n.e.) …Non-renewable energy resource of the building component layer in [MJ/m²]

(GWP) ……Global warming potential of the building component layer in [kg CO_2 äqui/m²]

(AP) ……Acidification potential of the building component layer in [kg SO_2 äqui/m²]

2.1.2 Calculation of the heating demand / energy certificates

For the two existing buildings ("A", "B") the layered component structures were largely known. The superstructures were either visible in existing plans or the occupants provided this information. Therefore, these superstructures could be used as input data into for the heating demand / energy certificate calculations. However, the conductivity values had to be taken from catalogues.

As a result the derived results are based on the layer components, but not necessarily on the correct lambda-values.

The two existing buildings, which were used in this thesis are located beside each other. (The fictive) House C was assumed to be built in close vicinity of the other houses on a yet unoccupied piece of land. This means that the microclimate can be assumed to be identical for all evaluated buildings. In addition, the Austrian Standards and Guidelines for energy certificates demand the use of a generic reference climate file.

The derived Key Performance Indicator was the on-site heating demand, normalized via the gross area of the buildings (kilowatt hours per square meter and year).

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2.2 Statistical Analysis / Used Software Tools

In a first approach to the thesis's topic 2D plans and 3D models of the two existing houses were drawn in Graphisoft ArchiCad 23 (2019). These plans and models were based on existing submission plans and inventory plans. Missing dimensions were measured by the author and added to the plans. These plans have been used for all further inquiries.

Building Energy Certificates were created with A-Null Development ArchiPhysik 15.0.65 (2018). The section "space heating and hot water supply" of the energy certificate program was filled out together with the residents to bring in their experiences and occupancy model.

One of the building occupants has been carefully collecting consumption values for electricity, water, and gas for both buildings. This data was brought together, structured, and analyzed in a spreadsheet for further statistical analysis in the framework of this thesis.

The outcome of this is included in the results for the two existing buildings.

To determine the environmental impact the datasets of ökobau.dat, and the results from ArchiPhysik (IBO 2008, IBO 2013 and baubook) are used.

Other calculations were done with Excel or manually by using a scientific calculator.

2.3 Location / Building Site

The buildings that are utilized for the conduction of this case study are located in Langenlois in Lower Austria, which is one of the nine federal provinces of Austria. The city Langenlois is located in the north-western quarter of Lower Austria. This area is known as the Waldviertel. Langenlois is about 75 km away from Vienna, the capital of Austria (Figure 1).

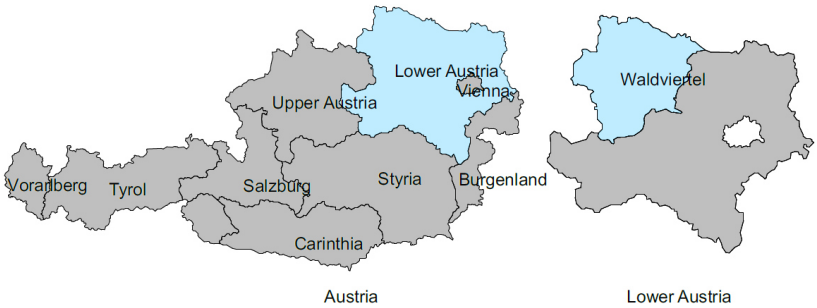

Figure 1: left: Austria with its federal states; right: Lower Austria with the corresponding Quarter of building location (source: illustration by the author)

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The two buildings are located in the southeast of the city. They are on the same plot of land and are seperated from each other only by a shared courtyard (Figure 2).

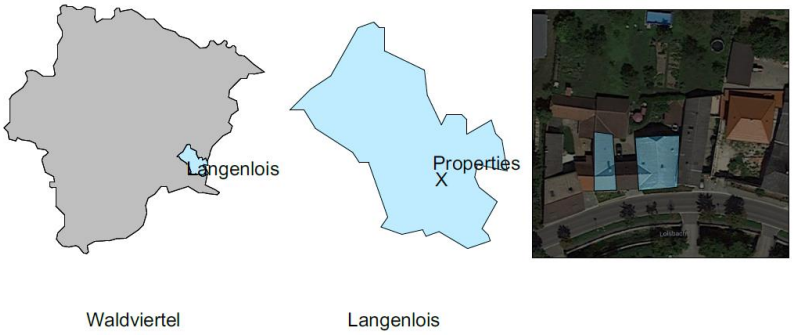

Figure 2: left: Location of Langenlois; middle: Location of properties within the city; right: Top view of Location of the two houses (source: left, middle: own representation; right: maps.google.com)

Figure 3 shows a site plan. The site is accessible from the street via a passageway gate to the courtyard. House A's entrance can be found on the left side, while house B's entrance is situated to the right side. House A has an adjoined, unheated garage connected at the north wall. This space is used to house agricultural vehicles and equipment as well as firewood and construction material. On its left side it borders on a passageway of the neighbor, which is open on two sides and only serves as shelter. House B is completely detached and does not have directly adjoined buildings.

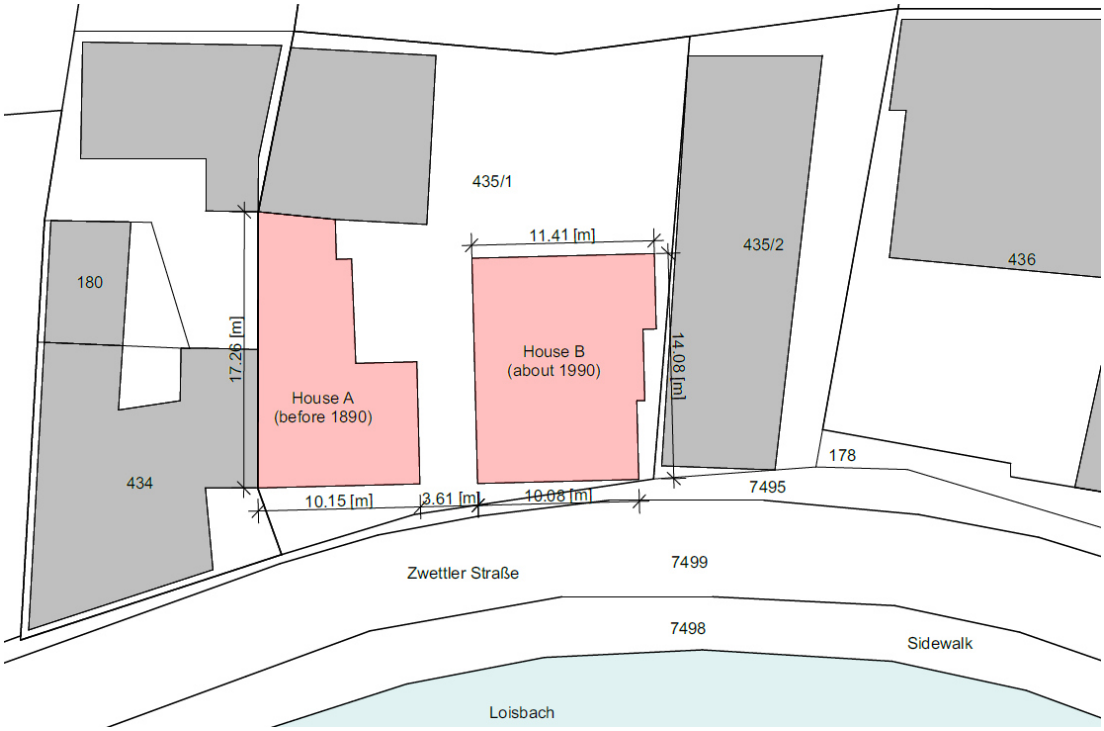

Figure 3: Site plan (source: illustration by the author)

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Figure 4 shows that the two buildings are connected through the unheated attic. While in reality, the large volume of the unheated shared attic space might show influence on the building's performance, it could be neglected for the normative calculations, as neither the heating demand nor the environmental impact calculation would be affected by its existence. The two houses are treated as two separate elements.

Figure 4: Photo – street view (source: illustration by the author)

2.4 Case Study buildings – the existing buildings

2.4.1 House A (Year of Construction: before 1890)

The date of construction of the older building is not exactly known. Until some years ago, the building was used by five occupants (a couple and three daughters). In the course of time, the father of the family passed away, and the children moved out. Today, one of the daughters uses House B together with her husband and two children. As such House A has a single occupant (the mother of the afore mentioned family). At the time of writing this work, the occupant was 87 years old.

<u>Building description:</u>

From the courtyard, two steps lead to the entrance door of House A. An anteroom leads to the kitchen and to the living room. One of two bedrooms can be accessed via the kitchen as well as via the living room. This bedroom and the living room have southward facing windows. The kitchen is adjoined by a small larder. The kitchen

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window is in the east wall facing the courtyard. A windowless corridor directed to the North leads to the second bedroom, and to the sanitary facilities (toilet and bathroom). The second bedroom has two windows on the east side. Figure 5 provides a plan of House A.

Scaled plans including all dimensions can be found in the appendix.

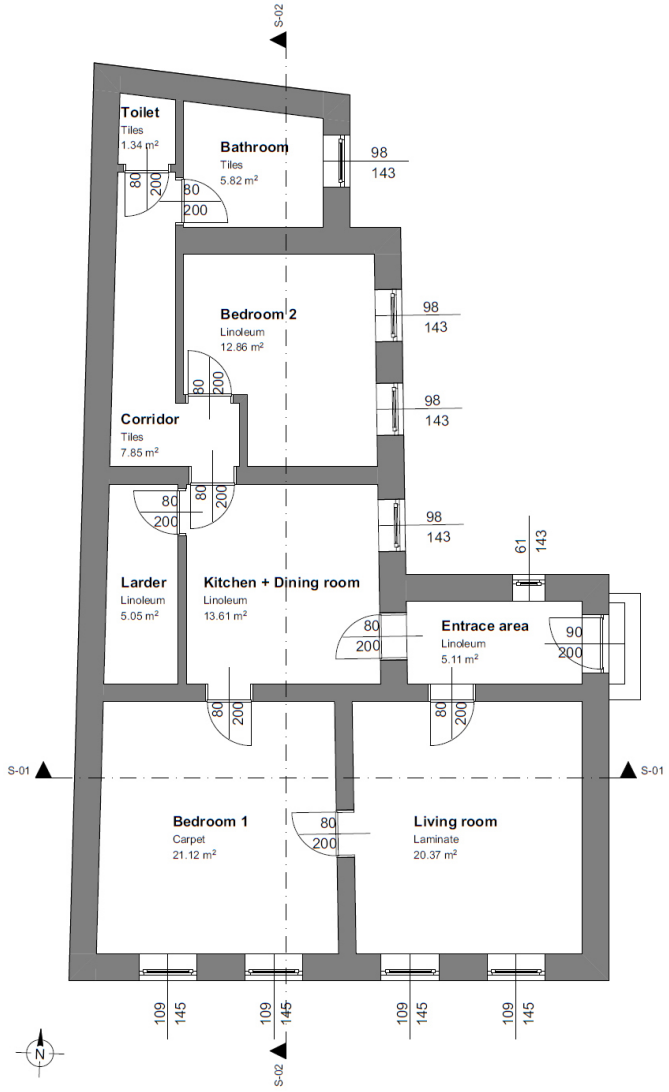

Figure 5: Ground Floor - House A (source: illustration by the author)

The room height of all rooms is 2.85 m. The attic is not heated. It is currently only used as storage space. The access to the attic space is only possible from the courtyard / garden, there is no stairway inside the heated volume. Figure 6 represents two sections of House A.

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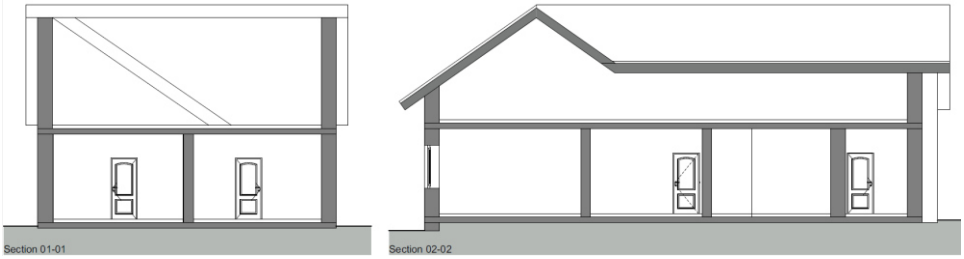

Figure 6: Sections - House A (source: illustration by the author)

The western wall faces the yard of the neighbour. This side of the building is therefore designed as a windowless firewall. Attached on the northern wall is an unheated enclosed garage, resulting in the absence of windows facing to the north. Moreover, there is no direct access to the garage from the heated volume. (Figure 7).

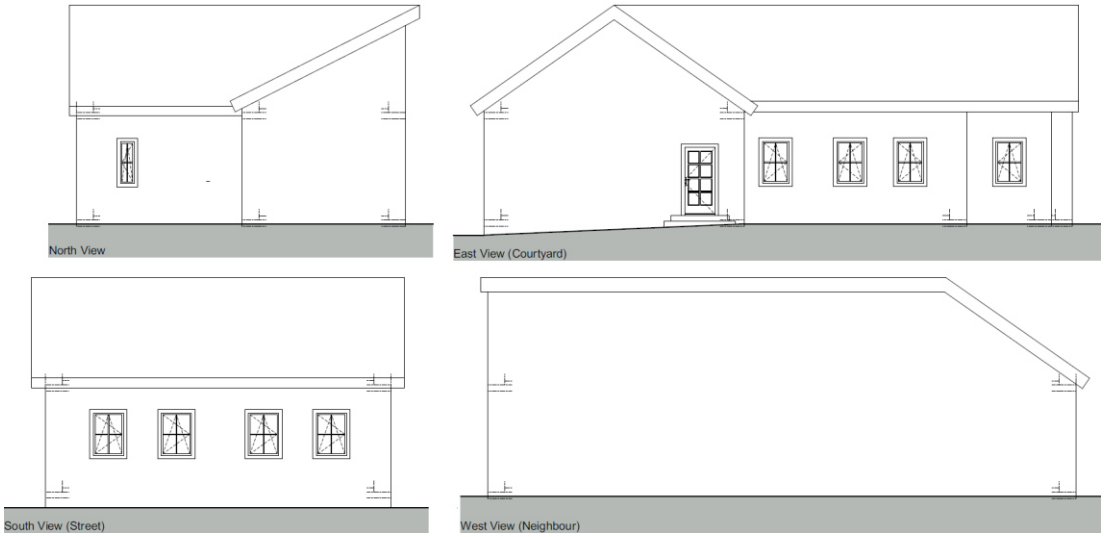

Figure 7: Views - House A (source: illustration by the author)

Figure 8 sums up basic facts of House A and illustrates its shape by means of the 3D model (Point of view from southeast, 3D model generated with ArchiCad 23).

Address:	Langenlois, Zwettler Straße		
Geographic location:	legth:	15° 40' 2.1"	East
	width:	48° 28' 28.7"	North
Owner:	Family Traxler		
Building type:	Single Family House		
Heated living area:	93.13 m²		
Heated gross area:	129.19 m²		
Heated gross volume:	445.71 m³		
Year of construction:	before 1890		
Construction type:	Bricks and stones (different types of masonry)		

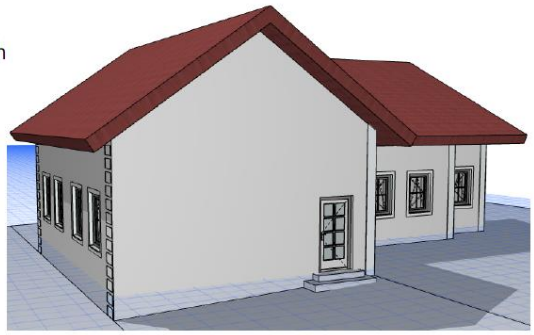

Figure 8: Fact sheet - House A (source: illustration by the author)

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2.4.2 House B (Year of Construction: 1990)

House B was built in 1990. The building is currently used by a couple and their two children. The mother of this family is one of the daughters of the lady living in House A – as afore mentioned.

Building Description:

Through the entrance area one gets to a central corridor. This corridor leads to all other rooms of the ground floor. There is a kitchen with a dining room and an adjoining larder, a living room, a bathroom, a toilet, a bedroom for the adults' and two rooms for the two children. Figure 9 provides a plan of the ground floor of House B.

Scaled plans including all dimensions can be found in the appendix.

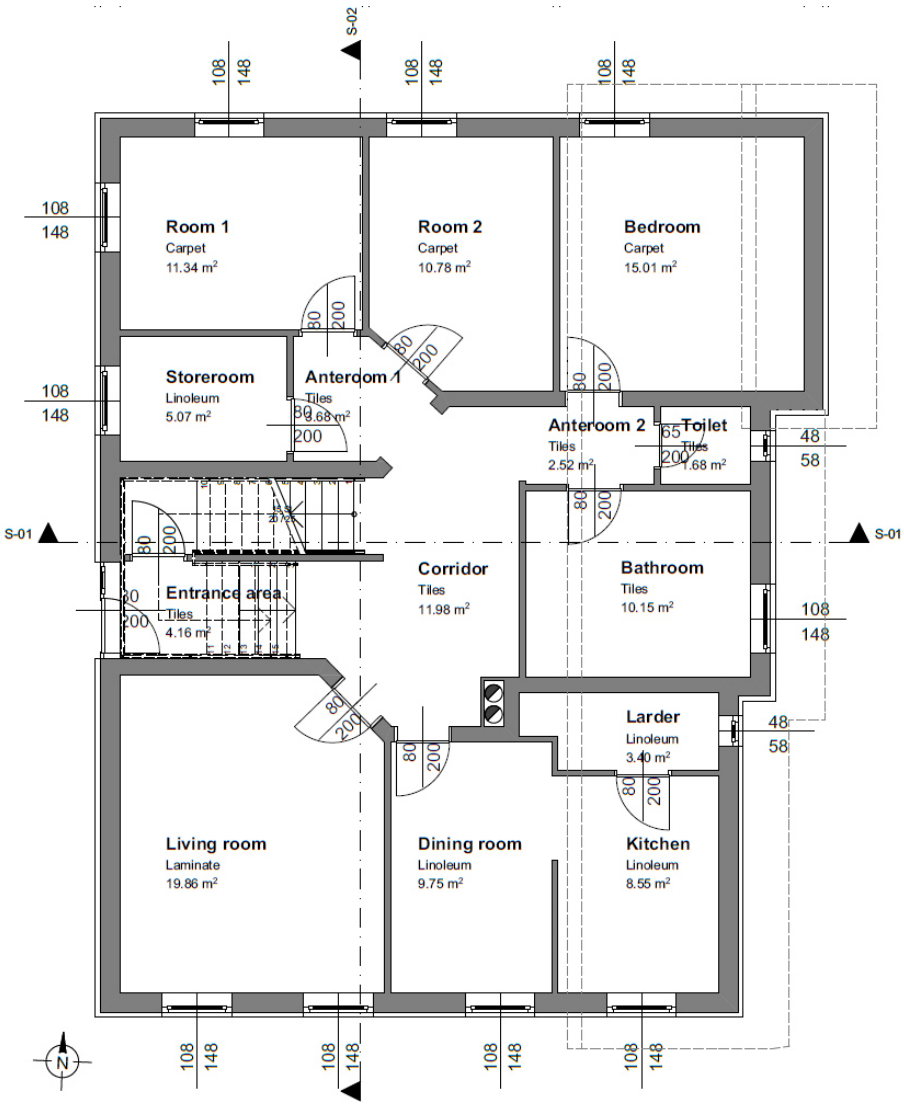

Figure 9: Ground floor - House B (source: illustration by the author)

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From the entrance area there is also the possibility to get into the basement. The basement of the house is not heated. There is a central corridor which leads to a workshop, an emergency shelter, some cellar rooms for storage and a heating room. The fuel storage room is accessible via the heating room. Figure 10 provides a plan of the basement of House B.

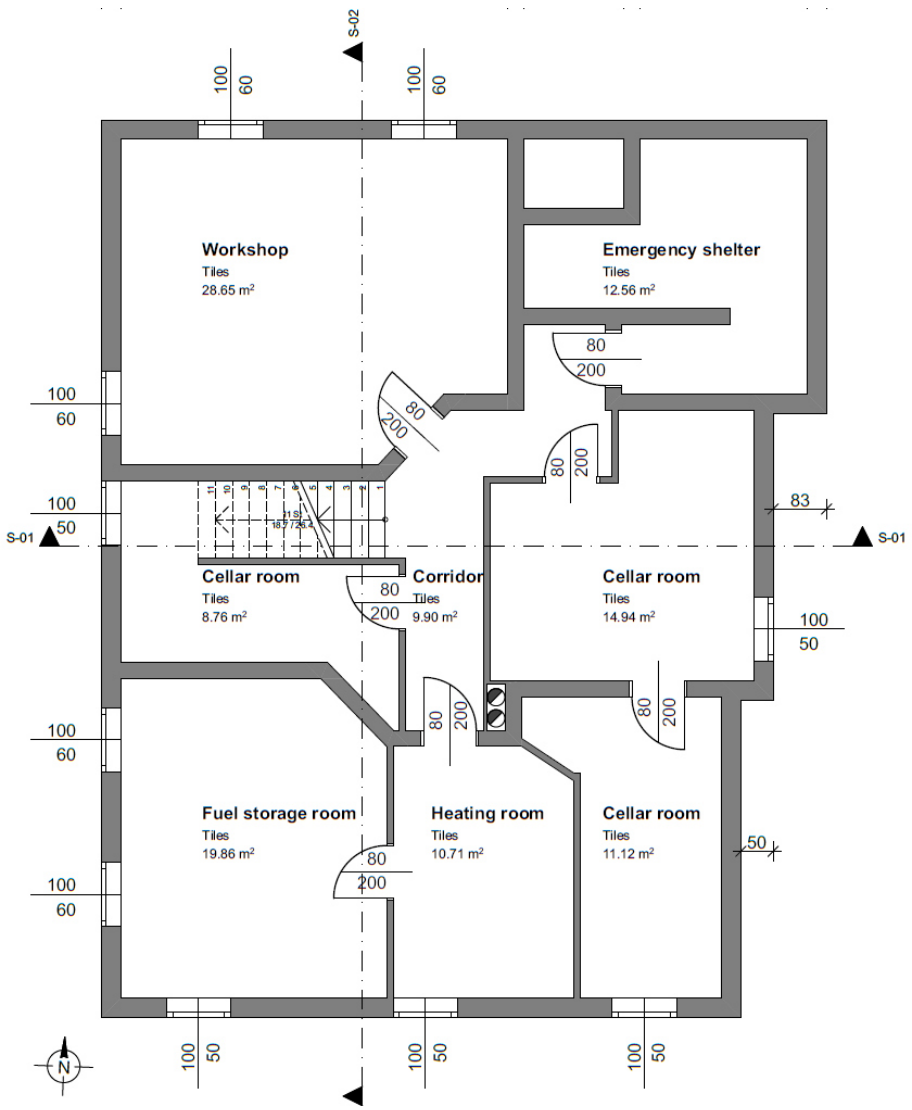

Figure 10: Basement - House B (source: illustration by the author)

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As in House A, also the attic space of House B is unheated. It is currently only used as storage space. The access to the attic space is possible via the stairway located in the corridor inside the heated volume.

Figure 11 provides a plan of the attic space of House B.

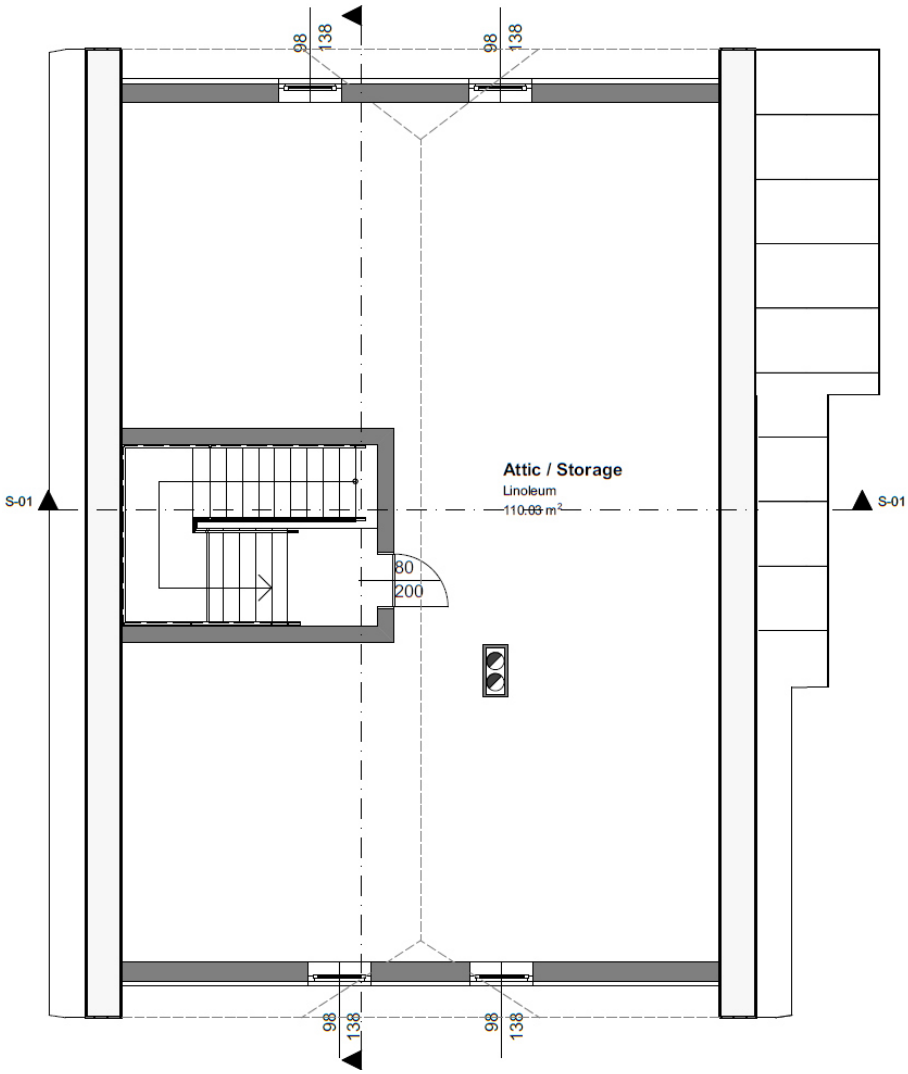

Figure 11: Attic - House B (source: illustration by the author)

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The room height of all rooms of the ground floor is 2.70 m. Figure 12 shows two sections of House B.

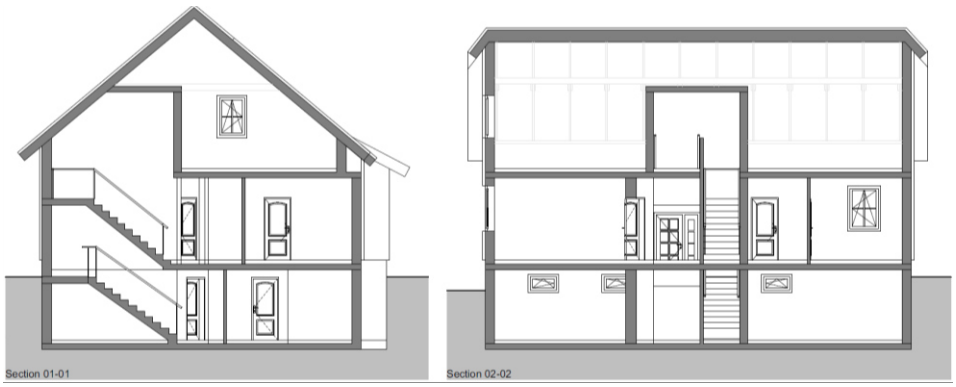

Figure 12: Sections - House B (source: illustration by the author)

Figure 13 shows the views of House B. The easter wall has setbacks in order to make optimum use of the existing space and avoid sloping walls. This was already evident in the floor plans in Figure 9 and Figure 10.

Figure 13: Views - House B (source: illustration by the author)

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Figure 14 sums up basic facts of House B and illustrates its shape by means of the 3D model (Point of view from the street, 3D model generated with ArchiCad 23).

Address:	Langenlois, Zwettler Straße		
Geographic location:	legth:	15° 40' 3.0"	East
	width:	48° 28' 28.6"	North
Owner:	Family Schmidt		
Building type:	Single Family House		
Heated living area:	117.93 m²		
Heated gross area:	150.42 m²		
Heated gross volume:	496.39 m³		
Year of construction:	1990		
Construction type:	Bricks made of lightweight concrete with expanded clay		

Figure 14: Fact sheet - House B (source: illustration by the author)

For the calculation of House B, it is assumed in the Scenarios, that it has no basement. This assumption should enable a better comparison of the individual buildings and scenarios.

2.5 The Fictitious Building – the new construction

2.5.1 House C (Year of Construction: 2020)

House C is a new built fictitious building. It serves as a comparison object to the two existing buildings that are to be renovated.

<u>Building Description:</u>

It is assumed that this building will be built north of the two existing houses. There is an open area that currently serves as garden but could be built on. This means that all three buildings are in the immediate vicinity and thus have the same weather conditions and site temperatures. For a better comparability to one of the two existing buildings, House C was assumed to be of similar heated gross area and shape as the building from 1990 (“B”). Therefore, the ground floors, sections and views are the same.

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Figure 15 shows a plan of the ground floor. It was assumed that the same fuel (gas) will be used for heating as for the two existing buildings.

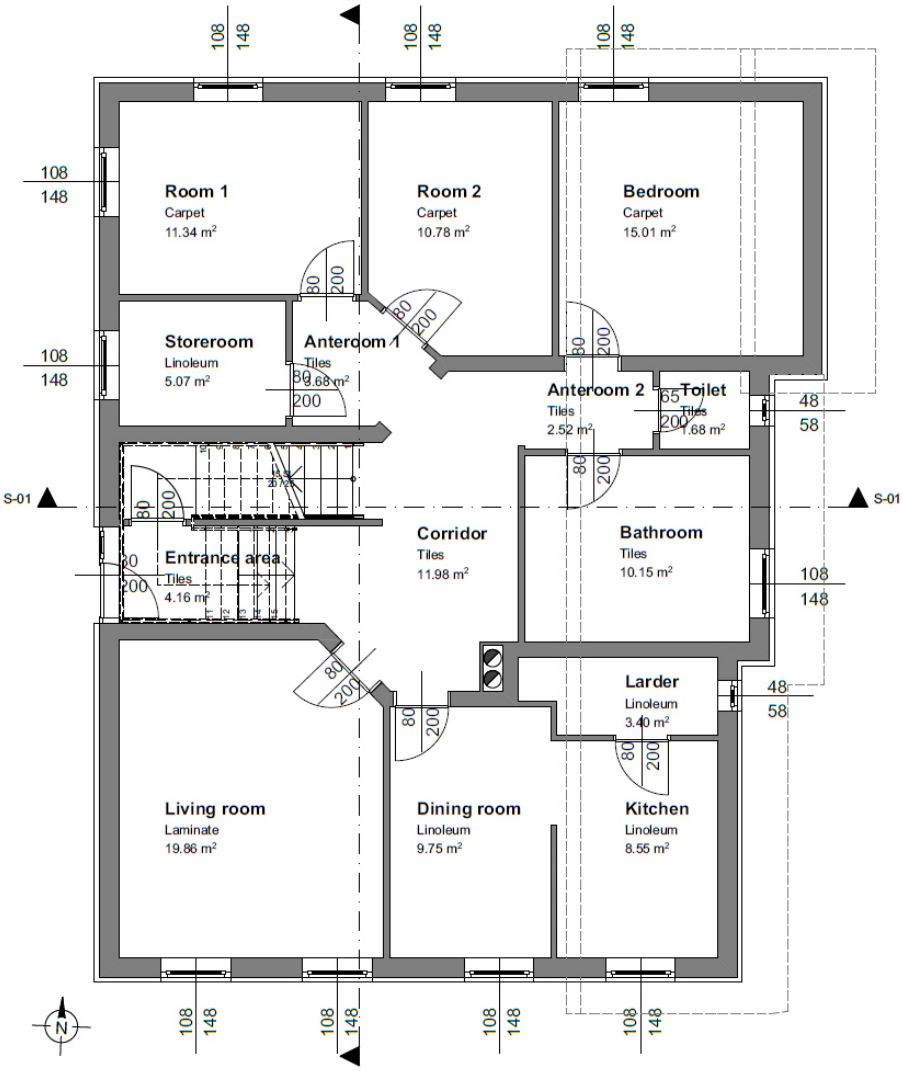

Figure 15: Ground floor – House C (source: illustration by the author)

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2.6 Scenarios

The different scenarios considered in this master thesis and the corresponding naming conventions are briefly described below.

Each house is identified by a letter:

A … House A (house built before 1890)

B … House B (house built in 1990)

C … House C (envisioned new building)

The number that can be found after the identification letter for House A and B is meant as consecutive numbering of scenarios. Thereby the following retrofit options are considered:

1 … Window change

2 … Adding (additional) insulation

3 … Bringing the House to Low Energy Standard (regarding HWB of the Energy Certificate)

A second number can be found for variations within the scenario.

This additional number is added to look at what happens if other materials are used for the specific retrofit option. For instance, when as retrofit option the windows were changed, another type of glass and another kind of frame was used. In the case of adding thermal insulation, experiments were made with different insulation materials – for instance between EPS/XPS and wood fiber boards.

All scenarios are briefly discussed below. Comprehensive descriptions of the building components assumed for each scenario can be found in the Appendix.

2.6.1 Scenario A.1.1 – Window exchange House A

In Scenario A.1.1 the windows of House A will be exchanged. Concerning the glazing, the current double glazing will be exchanged for a triple heat protection glazing. The old plastic frames are replaced by wood-aluminium frames.

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2.6.2 Scenario A.1.2 – Window exchange House A (other materials used)

Scenario A.1.2 is quite like the one before. In contrast here, materials are to be used that are said to be even more ecologically. The aim is, to check whether this is really the case. Thus, a triple glazing with the name “ökostar” should be used for glazing. For the frame, the aluminium cladding is omitted, and a simple wooden frame is used.

2.6.3 Scenario A.2.1 – Insulate Exterior walls and ceiling to unheated attic of House A with EPS/XPS

For Scenario A.2.1 the old plaster of the whole façade has to be removed in order to install insulation to the walls. After installing an EPS insulation of 15 cm thickness, a new heat insulation plaster is added.

A 10 cm thick XPS board is added to the ceiling to the unheated attic. On top of this, an additional OSB board will be added. In this scenario the floors remain as they are.

2.6.4 Scenario A.2.2 – Insulate Exterior walls and ceiling to unheated attic of House A with wood fiber insulation boards

For Scenario A.2.2 both the walls and the ceiling to the unheated attic are insulated with wood fiber insulation boards. This scenario is intended to show whether there are advantages in using a different material for insulation. In order to compare the environmental impact of different insulation variants the same insulation thicknesses are used as already for Scenario A.2.1.

2.6.5 Scenario A.3 – Bringing House A to Low Energy Standard

In Scenario A.3 all windows and the entrance door are swapped. All exterior walls are insulated with a 20 cm thick EPS insulation. In addition to this, the ceiling to the unheated attic and the ground will also be renovated. The existing floor covering, the concrete, the gravel and a layer of soil are removed. Afterwards, a new floor construction is installed again. All these measures make it possible to convert the existing building into a low-energy building.

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The measures taken in this Scenario are associated with high material requirements. It is to be shown whether the many materials that are removed have some disadvantages regarding the environmental impact that are not obvious at first glance.

2.6.6 Scenario B.1.1 – Window exchange House B

In this Scenario the windows of House B are going to be renovated. The original double glazing is changed to triple glazing. The plastic frames which are used currently are removed and new wood frames with aluminum cladding are used instead.

2.6.7 Scenario B.1.2 – Window exchange House B (other materials used)

Scenario B.1.2 is a modification of Scenario B.1.1. As has already been done for House A, this second Scenario for House B again uses materials that are said to be more ecological. Concerning the frames, the aluminum cladding is omitted, and a pure wooden window construction is used.

2.6.8 Scenario B.2.1 – Insulate Exterior walls and ceiling to unheated attic of House B with EPS/XPS

If one wants to insulate a house, the first thought is usually to simply use the materials EPS and XPS. Therefore, in this Scenario these two materials are used to insulate the exterior walls and the ceiling to the unheated attic. In this Scenario windows and floors remain as they are.

The existing 8 cm thick insulation on this Building will be removed and a new 15 cm thick insulation will be applied. The old insulation is therefore removed to avoid possible consequential damage in a few years. The originally 3 cm thick insulation of the ceiling to the unheated attic is also exchanged for 10 cm XPS insulation.

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2.6.9 Scenario B.2.2 – Insulate Exterior walls and ceiling to unheated attic of House B with wood fiber insulation boards

In this Scenario the exterior walls and the ceiling to the unheated attic are renovated and therefore insulated. In contrast to Scenario B.1.2, this Scenario is based on a more ecological material. Instead of using EPS and XPS, wood fiber insulation boards are used here. The study is intended to show whether they are more environmentally friendly than ordinary EPS and XPS. To compare the materials directly with each other, the same insulation thicknesses are used both in Scenario B.2.1 and in this.

2.6.10 Scenario B.3 – Bringing House B to Low Energy Standard

In Scenario B.3 all building elements except the interior walls are renovated. For window constructions a triple glazing and a wooden frame is used. In this scenario also the entrance door is renovated. The original 8 cm thick insulation of House B is removed, and a 20 cm thick EPS insulation is used instead. A thermal insulation plaster is then applied to this layer. As already in Scenario B.2.1 and B.2.2, the original 3 cm thick insulation and the cement screed are removed at the ceiling to the unheated attic. Here, a 20 cm thick XPS insulation is applied and a 1,5 cm thick oriented strand board is laid on top. The old floor structure is removed completely except for the gravel and replaced by a new structure with thermal insulation. These measures will bring House B up to low energy standard in terms of heating requirements.

2.6.11 Scenario C – New Construction of House C

Scenario C deals with a fictitious building that is newly constructed. In Scenario C this building is constructed in brick, as was already the case with the two existing buildings. This Scenario thus serves as a comparison as to whether various renovation measures of the previous Scenarios described above are preferable to a new construction from an ecological point of view. Since this study works with the background of urban sprawl, no other building will be demolished here. The building will be erected on land which hasn't been built on before. The shape of House C, the heated floor area and the volume are identical to that of House B.

In this Scenario also the construction of the roof has to be calculated and implemented in the results.

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A graphical overview of all eleven conducted Scenarios is provided in Figure 16.

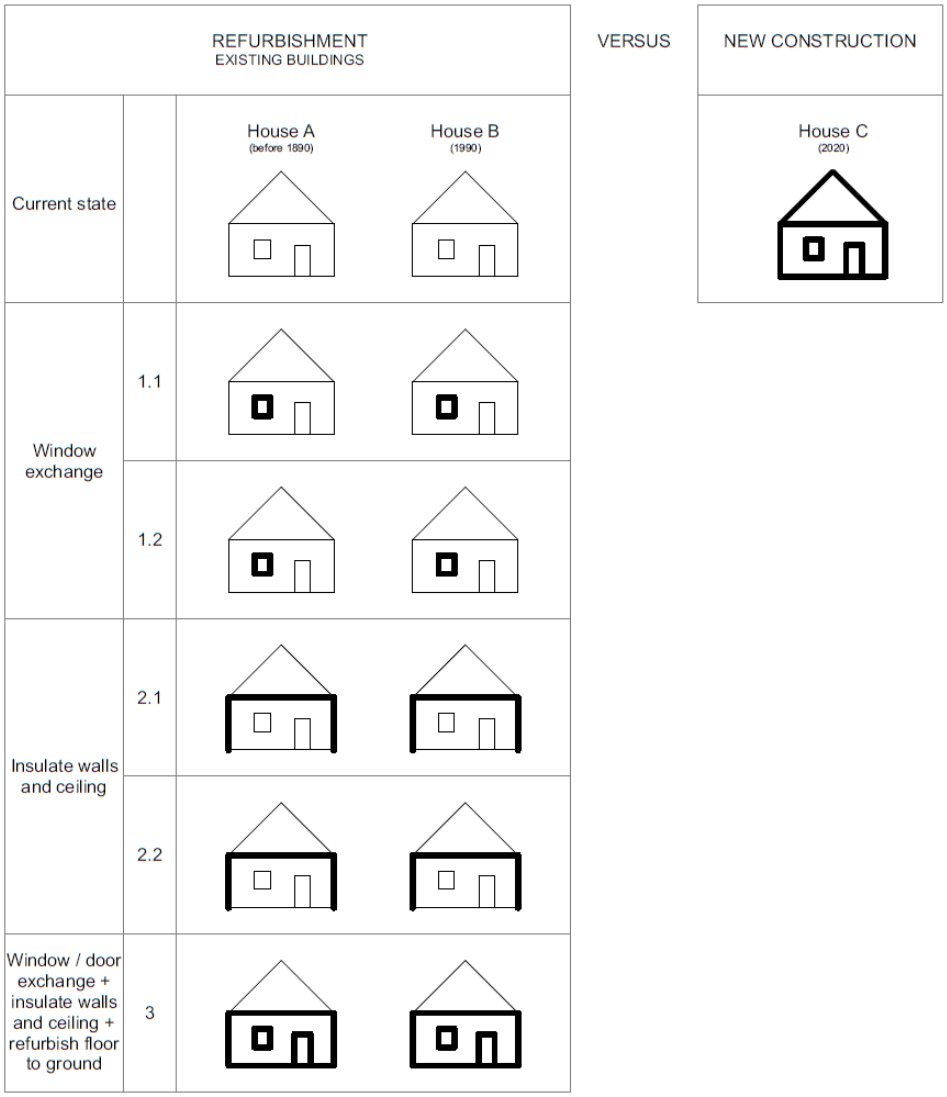

Figure 16: Overview of all eleven Scenarios (source: illustration by the author)

Detailed tables describing the relevant properties of each building constituent can be found in the Appendix.

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2.7 System Boundaries

Figure 17 illustrates the (time and process) system boundary used in the conducted analysis. The starting point for this study was set to 2020. It was assumed that the renovation measures as well as the construction of the new building should take place in 2020.

All the materials which are demolished from the existing buildings, as well as all new materials that are added to the constructions are included in the study. The recycling potential of materials is neglected.

House C was assumed to be built in close vicinity of the other houses but on a yet unoccupied piece of land. As such there will be no demolition waste in Scenario C. The newly erected building is going to be constructed on a site that has not yet been built on.

In addition, the upcoming 50 years of building operation are considered. The HWB value resulting from the energy certificates is used for this purpose, assuming that no major changes are conducted in the upcoming 50 years.

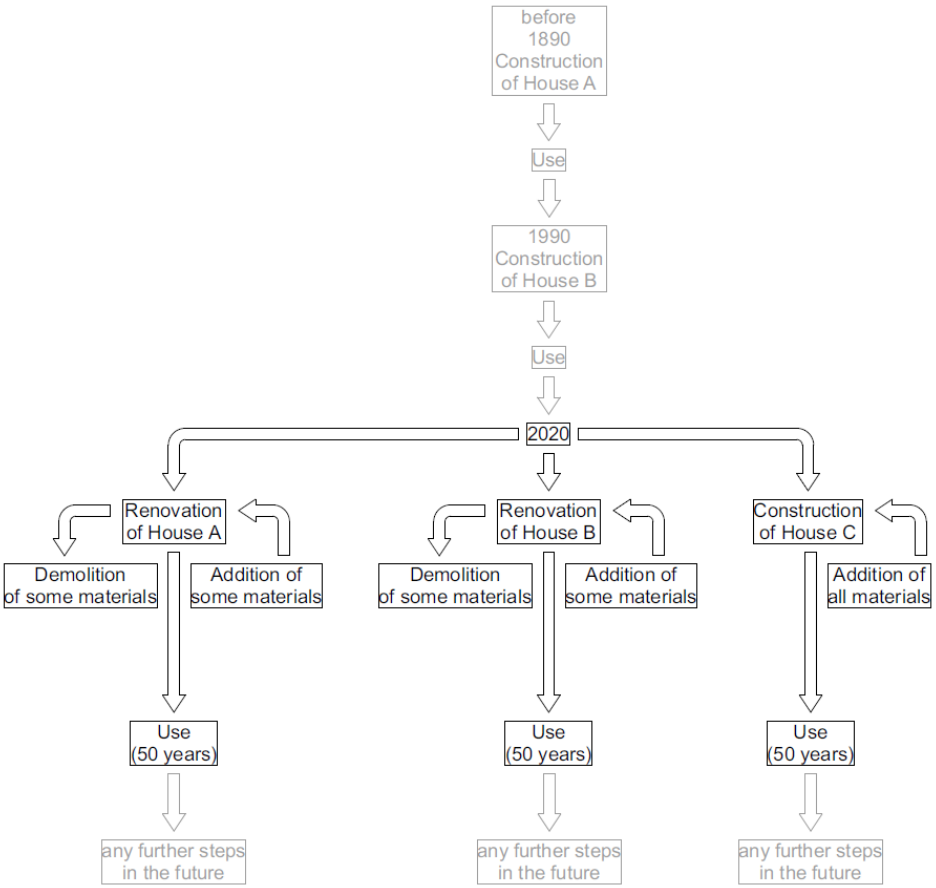

Figure 17: System Boundaries (source: illustration by the author)

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The service life of the materials used is also considered during this period. If necessary, component layers must be removed, and new ones applied.

The data for this is based on the duration-of-use-catalogue of the Austrian Institute for Building and Ecology (IBO 2018). The table below (Table 2) shows different categories of materials and how many years of use are expected.

Table 2: Duration-of-use-catalogue (source: illustration by the author inspired by (IBO 2018))

Construction	Description / Materials	Period of use
Primary construction	Supporting structure	100 years
Secondary construction	All construction layers except: Windows, thermal insulation system, sealings, foils, (floor coverngs) and building service components	50 years
Windows	Glazing, frame, window components	35 years
Thermal insulation system (including plaster, reinforcement fabrics)	Thermal insulation sysems made of masonry plaster base boards, EPS-F, heatinsulating mneral foam sheets, cork insulating slabs, hemp insulation, etc.	35 years
Plaster	Plaster including bases	35 years
Sealing / Foils: 35 a	Alu-bitumen sealing, alu vapour barrier, bitumen, bituminous coat, bituminized felt, etc.	35 years
Sealing / Foils: 25 a	Construction foil made of rubber (EPDM), PE- and PVC-sealing, building paper, other sealings except bituminous sealings, metal-clad fols, etc.	25 years
Floor coverings: 50 a	Solid wood ground, solid parquet, ceramic tiles, natural stone, artifical stone, etc.	50 years
Floor coverings: 25 a	Multilayer parquet, laminate, linoleum, PVC floor covering, polyolefin floor covering on base of PE and PU, rubber floor covering, rubber-dimpled covering	25 years
Floor coverings: 10 a	Cork, textile floor coverings, etc	10 years
Floor and wall coating	Screed coating, varnish, wall paint, wallpaper, etc.	10 years
Tertiary construction	Technical building equipment (depends on components)	20 to 50 years

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3 RESULTS

3.1 Overview

In this Chapter the results of the individual scenarios described in Chapter 2 are presented (ten different scenarios for the two existing buildings, one scenario for the new constructed building, resulting in eleven different scenarios). The results of all evaluated scenarios are discussed one after the other. For the original states of House A and B additionally the collected water, electricity and gas demands are presented.

For each scenario the result of the Energy Certificate calculation is shown at the beginning. Subsequently, a list of removed and/or added building materials is provided, based on the corresponding measures in the specific retrofit scenario. The related environmental impact is also presented.

The next result item deals with the emissions produced during the use/occupancy phase. First and foremost, it is calculated how often various materials have to be replaced during the considered use phase of fifty years. The impact on the environment is again presented using the three OI3 indicators PEI n.e. (non-renewable energy resource requirement), GWP (global warming potential) and AP (acidification potential). Then the amount of CO_2 is calculated, which is produced due to the heating requirements of the Energy Certificates for heating the building.

Finally, a short summary of all calculated environmental impacts of the respective scenario is shown. This summary is presented in tabular form.

In Chapter 4, Discussion, the results of all scenarios are compared, critically analyzed, and discussed.

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3.2 House A

Energy Certificate:

The Energy Certificate of House A in Figure 18 shows that it would make sense to consider renovation measures in order to reduce the heating requirement and thus also the environmental impacts. The calculations have resulted in a heating demand (HWB_{SK}) of 499.55 $kWh.m^{-2}.a^{-1}$.

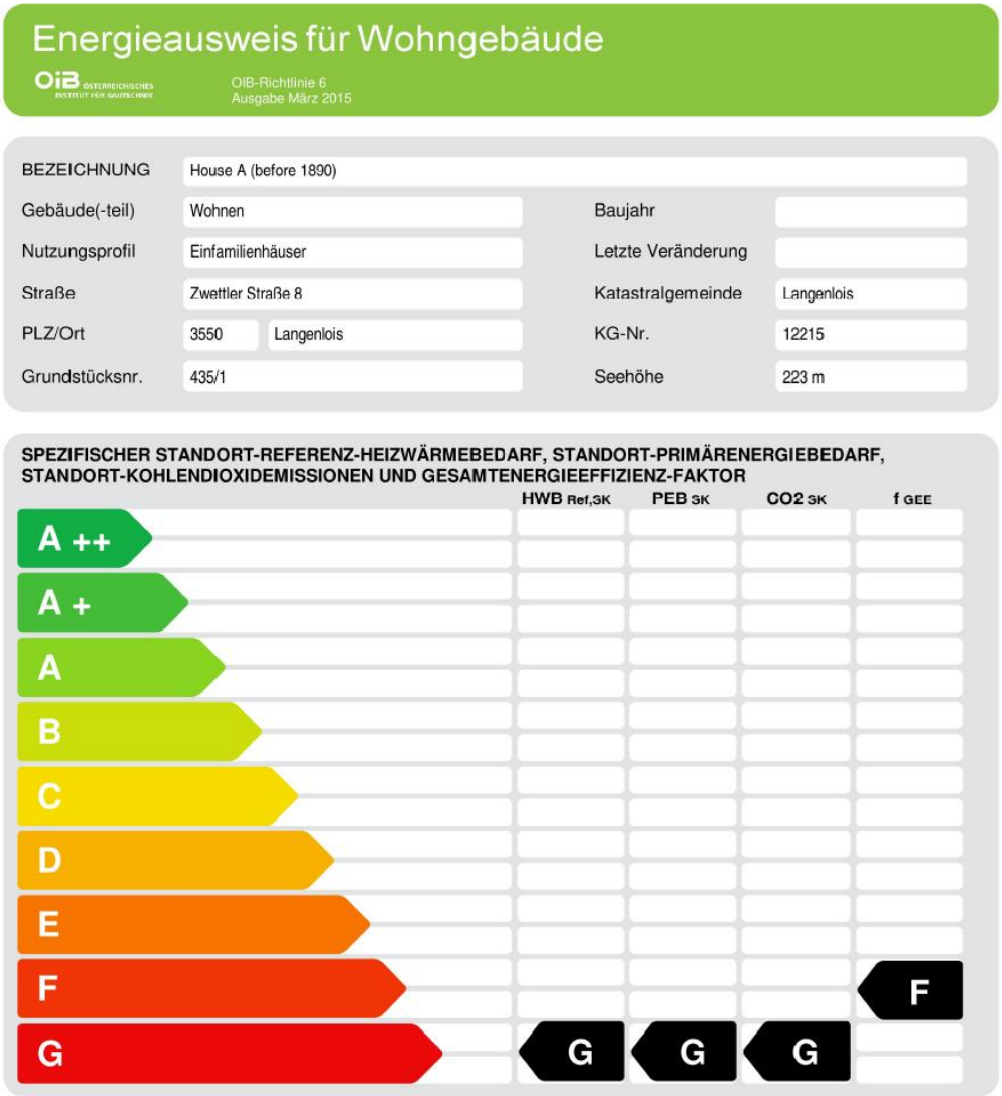

Figure 18: Energy Certificate House A (source: illustration taken from ArchiPhysik based on the author's case study buildings)

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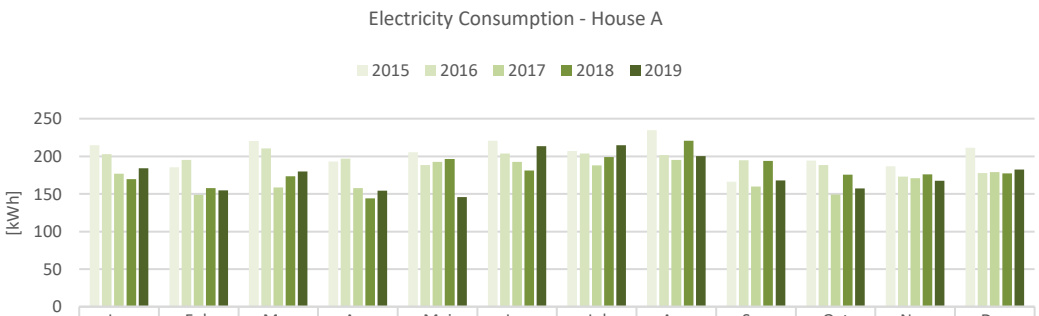
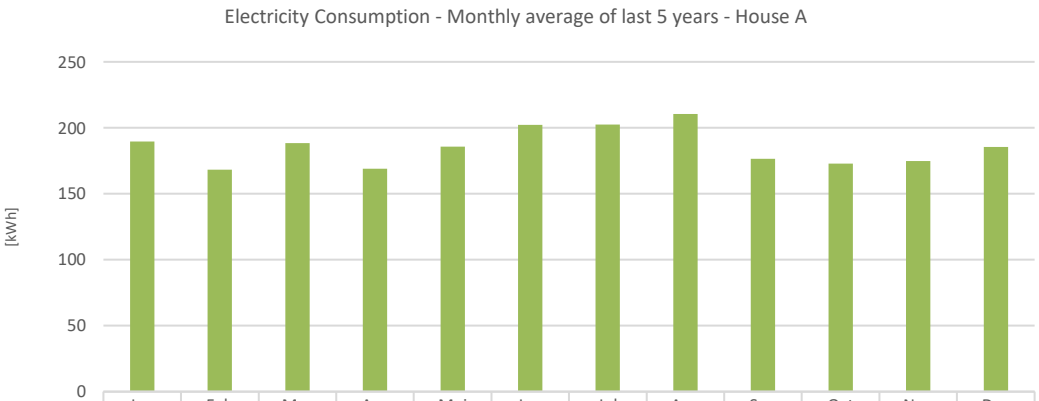
Current Electricity-, Gas- and Water Consumption:

The following Figures (Figure 19, Figure 20, Figure 21, Figure 22, Figure 23, and Figure 24) show the current gas consumption, electricity consumption and water consumption of House A. The values shown represent the monthly consumptions of the last five years (2019-2015).



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	214.6	185.4	220.2	192.9	205.2	220.5	207.1	234.7	166.3	194.4	186.8	211.5
2016	202.7	195.1	210.3	196.8	188.2	203.5	203.5	201.7	194.8	188.2	173.1	177.9
2017	176.9	148.6	158.5	157.6	192.6	192.6	187.9	195.3	159.6	149.2	170.9	179.1
2018	169.5	157.6	173.5	144.1	196.5	180.9	198.8	220.6	193.8	175.7	175.8	177.1
2019	184.2	154.7	179.7	154.1	145.7	213.5	214.7	200.3	167.9	157.1	167.4	182.3

Figure 19: Electricity Consumption House A (2015-2019) (source: illustration by the author)



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	189.6	168.3	188.4	169.1	185.6	202.2	202.4	210.5	176.5	172.9	174.8	185.6

Figure 20: Monthly Average Electricity Consumption of last 5 years - House A (2015-2019) (source: illustration by the author)

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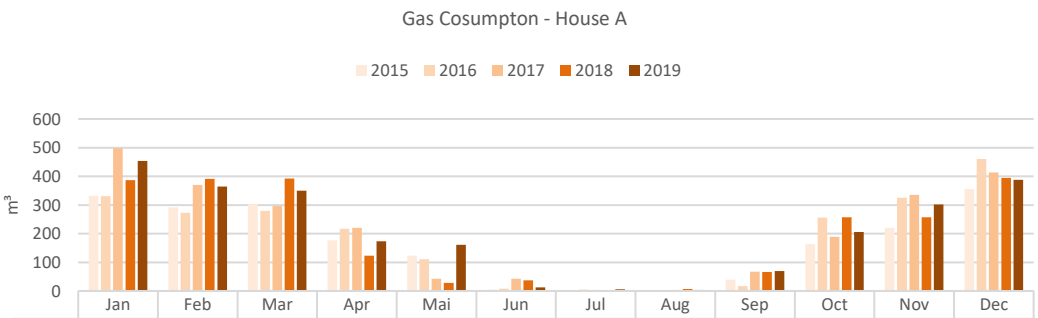
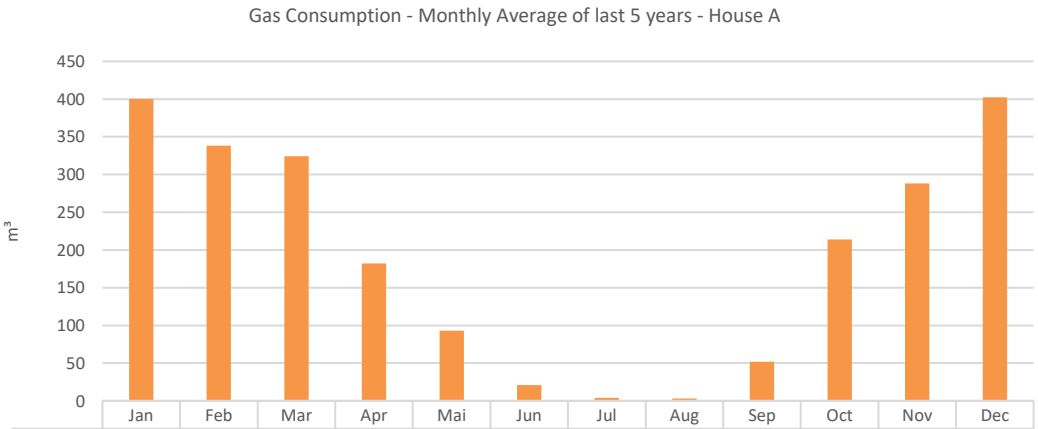


	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	332.1	292.1	303.0	176.8	122.6	4.5	2.2	0.8	39.1	162.9	220.2	355.0
2016	330.5	273.2	279.9	216.5	110.5	8.2	4.9	0.1	17.3	255.5	325.2	460.9
2017	498.7	369.8	296.3	220.3	43.0	43.0	4.1	3.2	66.9	188.8	335.3	413.4
2018	386.2	391.6	392.7	123.5	28.0	36.9	3.0	7.5	66.4	257.2	257.3	394.4
2019	453.6	364.3	349.6	173.6	160.8	12.7	5.8	3.1	69.2	205.9	302.2	387.4

Figure 21: Gas Consumption House A (2015-2019) (source: illustration by the author)



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	400.2	338.2	324.3	182.1	93.0	21.1	4.0	2.9	51.8	214.1	288.0	402.2

Figure 22: Monthly Average Gas Consumption of last 5 years - House A (2015-2019) (source: illustration by the author)

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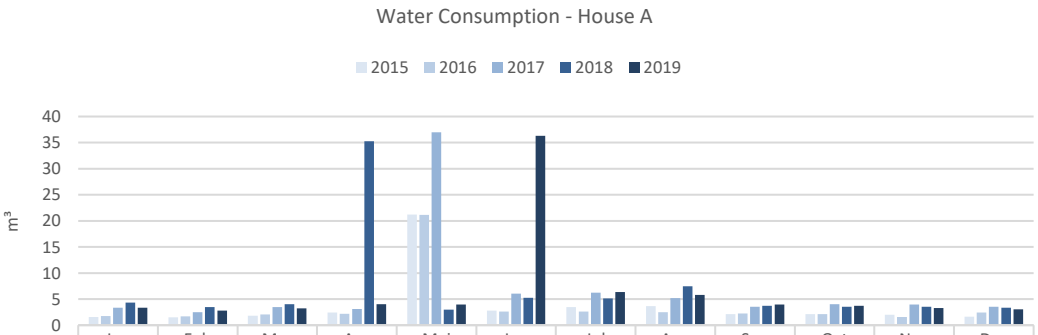
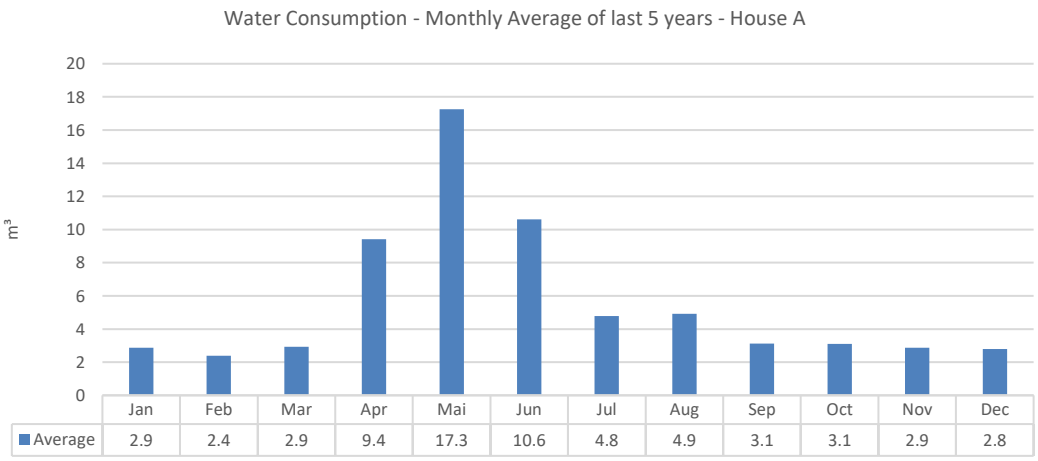
The outliers regarding the water consumption in Figure 23 and Figure 24 are due to the filling of the pool.



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	1.5	1.5	1.8	2.4	21.2	2.8	3.5	3.6	2.1	2.1	2.0	1.6
2016	1.8	1.7	2.1	2.2	21.1	2.6	2.6	2.5	2.3	2.1	1.6	2.4
2017	3.4	2.5	3.5	3.1	37.0	6.1	6.2	5.2	3.5	4.0	3.9	3.5
2018	4.4	3.5	4.0	35.3	3.0	5.3	5.2	7.5	3.7	3.5	3.5	3.4
2019	3.3	2.8	3.2	4.0	4.0	36.3	6.4	5.8	4.0	3.7	3.3	3.0

Figure 23: Water Consumption House A (2015-2019) (source: illustration by the author)



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	2.9	2.4	2.9	9.4	17.3	10.6	4.8	4.9	3.1	3.1	2.9	2.8

Figure 24: Monthly Average Water Consumption of last 5 years - House A (2015-2019) (source: illustration by the author)

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3.3 Scenario A.1.1

Energy Certificate:

Changing the double glazing to a triple heat protection glass and changing the plastic frames to wood-aluminium frames leaded to a heating demand of 488.32 kWh.m^{-2}.a^{-1}. This still corresponds to class G (Figure 25).

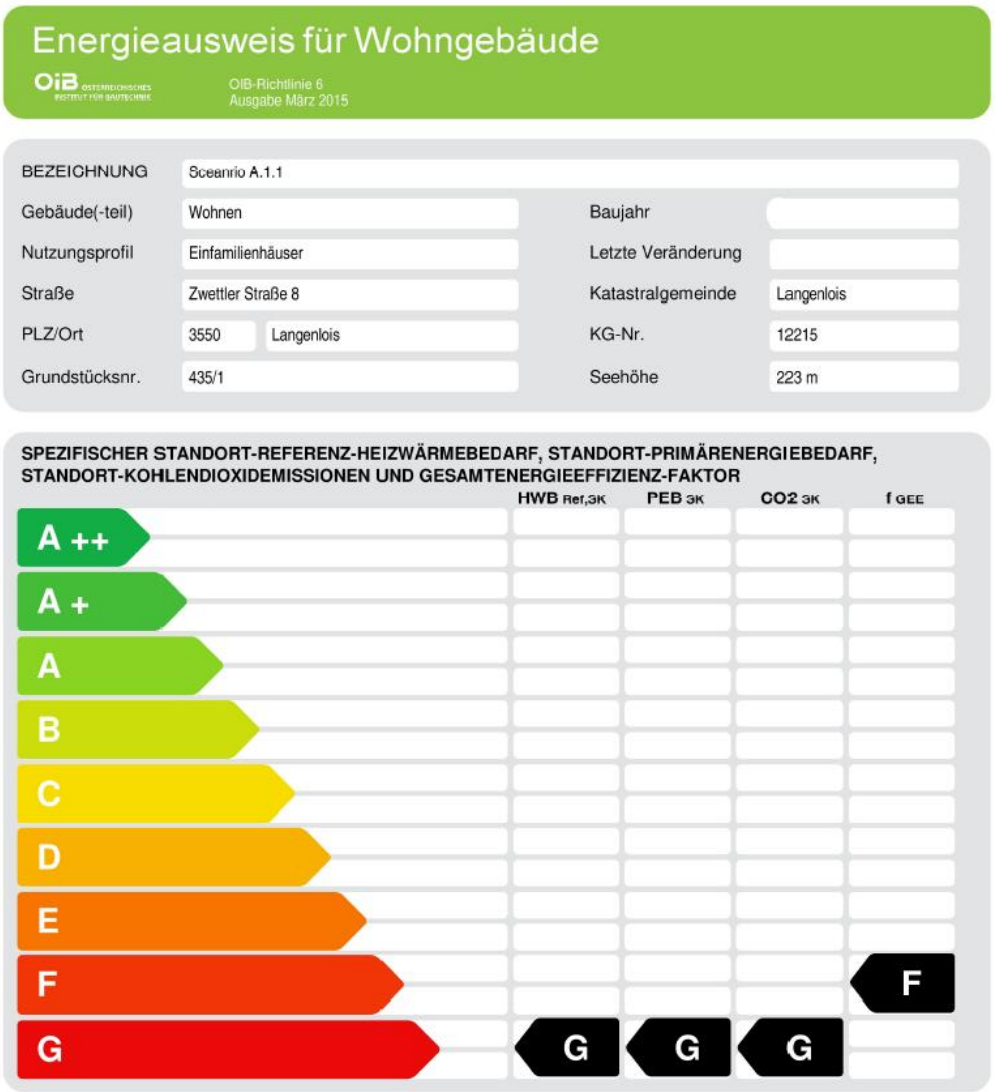

Figure 25: Energy Certificate Scenario A.1.1 (source: illustration taken from ArchiPhysik based on the author's case study buildings)

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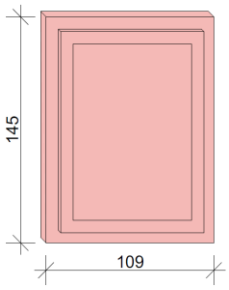
Impact of removal and impact of production of added materials:

Table 3 shows those impact values due to the removal of the current windows. The impact per square meter of the different used windows as well as the absolute impact of the individual window for this scenario is shown. The number of windows installed was also taken into account. Table 4 lists all newly inserted windows and their impact of production.

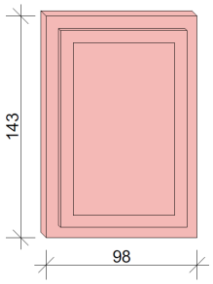
Table 3: Impact of removal (source: illustration by the author)

Window 01 (big)



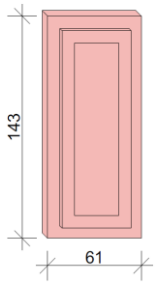
Double insulation glass			Impact per m²			Absolut Impact	
4.44	m² removed (4x1.11m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	21.22
		GWP	[kgCO$_2$.m^{-2}]	0.33	GWP	[kg CO$_2$]	1.47
		AP	[kgSO$_2$.m^{-2}]	0.00208	AP	[kg SO$_2$]	0.00924
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
1.88	m² removed (4x0.47m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	192.70
		GWP	[kgCO$_2$.m^{-2}]	48.21	GWP	[kg CO$_2$]	90.63
		AP	[kgSO$_2$.m^{-2}]	0.01091	AP	[kg SO$_2$]	0.02051
		Δ OI3	[Pkt/m²]	12.91			

Window 02 (middle)



Double insulation glass			Impact per m²			Absolut Impact	
3.84	m² removed (4x0.96m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	18.36
		GWP	[kgCO$_2$.m^{-2}]	0.33	GWP	[kg CO$_2$]	1.27
		AP	[kgSO$_2$.m^{-2}]	0.00208	AP	[kg SO$_2$]	0.00799
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
1.76	m² removed (4x0.44m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	180.40
		GWP	[kgCO$_2$.m^{-2}]	48.21	GWP	[kg CO$_2$]	84.85
		AP	[kgSO$_2$.m^{-2}]	0.01091	AP	[kg SO$_2$]	0.01920
		Δ OI3	[Pkt/m²]	12.91			

Window 03 (small)



Double insulation glass			Impact per m²			Absolut Impact	
0.50	m² removed (1x0.5m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	2.39
		GWP	[kgCO$_2$.m^{-2}]	0.33	GWP	[kg CO$_2$]	0.17
		AP	[kgSO$_2$.m^{-2}]	0.00208	AP	[kg SO$_2$]	0.00104
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
0.37	m² removed (1x0.37m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	37.93
		GWP	[kgCO$_2$.m^{-2}]	48.21	GWP	[kg CO$_2$]	17.84
		AP	[kgSO$_2$.m^{-2}]	0.01091	AP	[kg SO$_2$]	0.00404
		Δ OI3	[Pkt/m²]	12.91			

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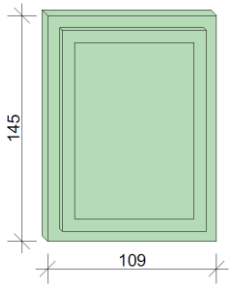
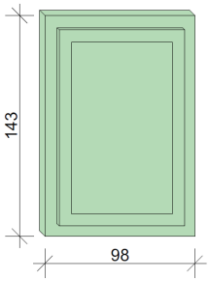
Table 4: Impact of production (source: illustration by the author)

Window 01 (big)



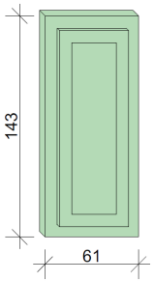
Triple heat protection glass			Impact per m²			Absolut Impact		
4.44	m² used (4x1.11m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	2370.78
		GWP	[kgCO_2.m⁻²]	40.77	GWP	[kg CO_2]	181.02
		AP	[kgSO_2.m⁻²]	0.31118	AP	[kg SO_2]	1.38164
		Δ OI3	[Pkt/m²]	66.08			
Wood-aluminium frame (d = 0.1m) - spruce wood							
1.88	m² used (4x0.47m²)	PEI n.e.	[MJ.m⁻²]	1741.86	PEI n.e.	[MJ]	3274.70
		GWP	[kgCO_2.m⁻²]	-9.89	GWP	[kg CO_2]	-18.59
		AP	[kgSO_2.m⁻²]	0.5226	AP	[kg SO_2]	0.98249
		Δ OI3	[Pkt/m²]	126.09			

Window 02 (middle)



Triple heat protection glass			Impact per m²			Absolut Impact		
3.84	m² used (4x0.96m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	2050.41
		GWP	[kgCO_2.m⁻²]	40.77	GWP	[kg CO_2]	156.56
		AP	[kgSO_2.m⁻²]	0.31118	AP	[kg SO_2]	1.19493
		Δ OI3	[Pkt/m²]	66.08			
Wood-aluminium frame (d = 0.1m) - spruce wood							
1.76	m² used (4x0.44m²)	PEI n.e.	[MJ.m⁻²]	1741.86	PEI n.e.	[MJ]	3065.67
		GWP	[kgCO_2.m⁻²]	-9.89	GWP	[kg CO_2]	-17.41
		AP	[kgSO_2.m⁻²]	0.5226	AP	[kg SO_2]	0.91978
		Δ OI3	[Pkt/m²]	126.09			

Window 03 (small)



Triple heat protection glass			Impact per m²			Absolut Impact		
0.50	m² used (1x0.50m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	266.98
		GWP	[kgCO_2.m⁻²]	40.77	GWP	[kg CO_2]	20.39
		AP	[kgSO_2.m⁻²]	0.31118	AP	[kg SO_2]	0.15559
		Δ OI3	[Pkt/m²]	66.08			
Wood-aluminium frame (d = 0.1m) - spruce wood							
0.37	m² used (1x0.37m²)	PEI n.e.	[MJ.m⁻²]	1741.86	PEI n.e.	[MJ]	644.49
		GWP	[kgCO_2.m⁻²]	-9.89	GWP	[kg CO_2]	-3.66
		AP	[kgSO_2.m⁻²]	0.5226	AP	[kg SO_2]	0.19336
		Δ OI3	[Pkt/m²]	126.09			

Influence of service life:

Life cycle assessment (LCA) also considers how often a component or component layer needs to be replaced during the period under consideration. In this study, a lifespan of 50 years is assumed as the period of consideration. As it is stated in Table 2, a service life of 35 years is expected for windows. This applies to the entire window construction. It therefore applies to both the frame and the glazing. In this scenario this would mean, that the windows would have to be changed once during the period under consideration. This measure also balances the environmental impact of both the disposal of the old windows and the production of the new windows.

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Table 5 shows how old existing building components are in 2020, which is the time of renovation. It also shows how often components need to be replaced during the observation period. The lifetimes were calculated based on those from the Austrian Institute for Building and Ecology, already shown in Table 2. For example, the floor coverings with carpet are already 38 years old in the existing building and are still in extremely good condition. Nevertheless, the recommended values were taken to calculate the impact for the period of use considered. That means that they must be exchanged.

The data in Table 5 apply to both Scenario A.1.1 and Scenario A.1.2.

Table 5: Substitution during the period under consderation (source: illustration by the author)

Material		Age in 2020 [years]	Period of use - according to IBO [years]	Substitution during the period under consideration
Primary construction: Supporting structure		~ 130	100	0*
Windows	refurbished	0	35	1
Plaster		23	35	2
Floor covering: ceramic tiles		28	50	1
Floor covering: linoleum		28	25	2
Floor covering: laminate		38	25	2
Floor covering: textile covering		38	10	5

* It was assumed that the supporting structure could continue to exist.

In Table 6 the impact for the necessary changings of materials during the period under consideration are shown.

Table 6: Impact of Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO_2.m⁻²]	Production GWP [kgCO_2.m⁻²]	** GWP [kg CO_2]	Removal AP [kgSO_2.m⁻²]	Production AP [kg SO_2.m⁻²]	** AP [kg SO_2]
Glazing (windows, door)	9.20	1	7.17	533.96	4,978.40	0.49	40.77	379.59	0.0031000	0.3112	2.89
Frame (windows, door)	5.39	1	0.44	1,741.86	9,391.00	40.37	- 9.89	164.29	0.0000420	0.5226	2.82
Plaster	240.76	2	4.72	29.76	16,602.81	0.34	3.15	1,680.50	0.0000884	0.0083	4.04
Floor covering: ceramic tiles	15.01	1	4.09	649.06	9,803.78	0.30	35.83	542.31	0.0018000	0.1288	1.96
Floor covering: linoleum	36.63	2	0.24	419.50	30,750.15	14.36	9.87	1,775.09	0.0000240	0.1040	7.62
Floor covering: laminate	20.37	2	0.15	176.15	7,182.46	11.80	0.88	516.58	0.0000140	0.0355	1.45
Floor covering: textile covering	21.12	5	1.61	82.44	8,875.68	4.05	1.92	630.43	0.0025000	0.0183	2.20
Sum					**87,584.28**			**5,688.80**			**22.97**

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Influence of heating demand:

According to the European Commission (Commission of the European Communities 2007), an average emission factor of 0.44 kg CO_2 per kWh can be assumed for heating with gas.

The results of the Energy Certificate from ArchiPhysik 15 displayed an annual heating demand of 488.32 kWh.m^{-2} for this Scenario. With a heated gross area of 129.90 m², this leads to the following results:

	Values per m²	Absolut values
Annual heating demand	488.32 kWh.m^{-2}	63,432.77 kWh
Impact		27,910.42 kg CO_2 (per year)

Summary of whole Scenario:

Table 7 shows the sum of all impacts resulting from Scenario A.1.1. The environmental impact in terms of heating requirement has already been summed up for the entire 50-year period under consideration.

Table 7: Sum for Scenario A.1.1 (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO_2]	AP [kg SO_2]	[kg CO_2]
Renovation measure	12,126.02	514.52	4.89	
Use (material exchages)	87,584.28	5,688.80	22.97	1,395,521.00
SUM	**99,710.30**	**6,203.32**	**27.86**	**1,395,521.00**

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3.4 Scenario A.1.2

Energy Certificate:

In this Scenario the glass of the windows was changed to a triple glazing called “ökostar”. The aluminium cladding was omitted for the frames and pure wooden frames were used. The described renovation measure resulted in a heating demand of 485.89 kWh.m^{-2}.a^{-1}, which is still energy class G (Figure 26).

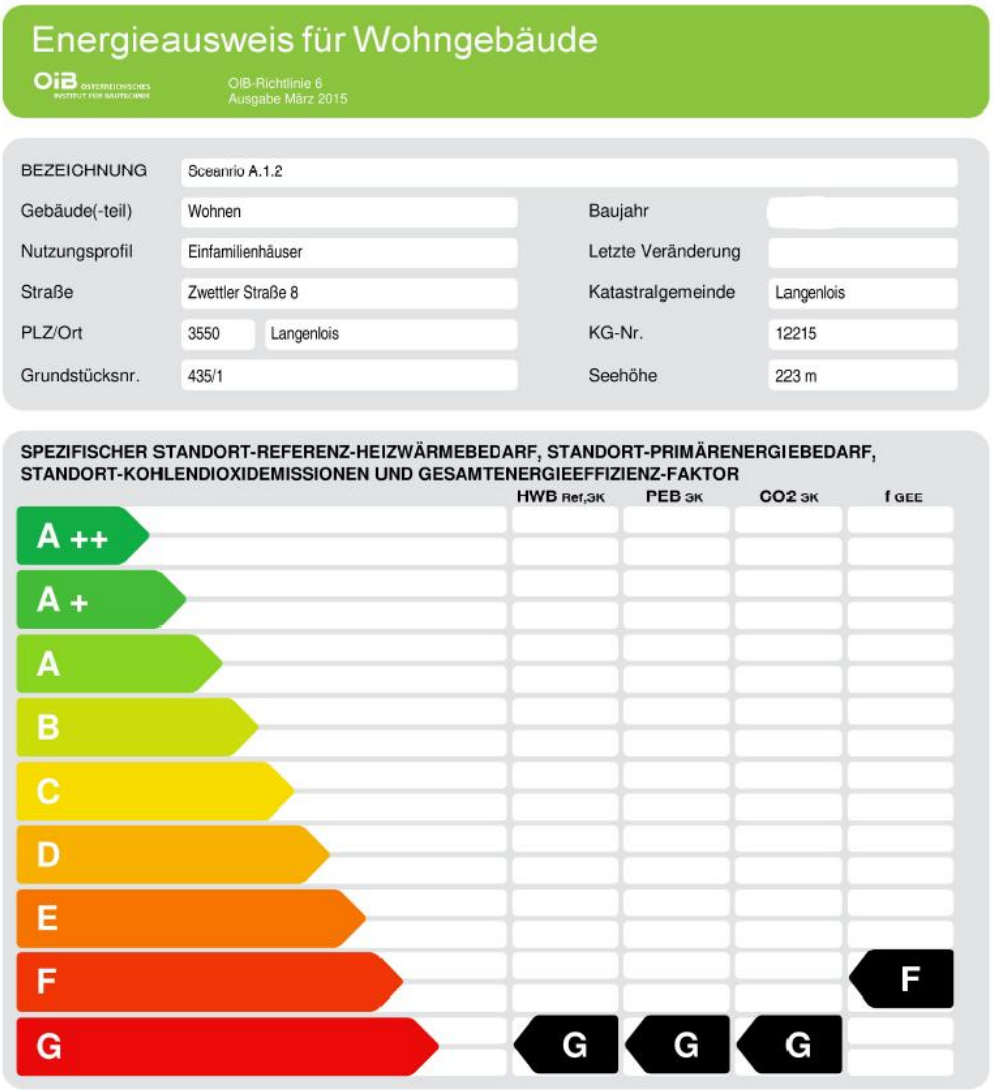

Figure 26: Energy Certificate Scenario A.1.2 (source: illustration taken from ArchiPhysik based on the author’s case study buildings)

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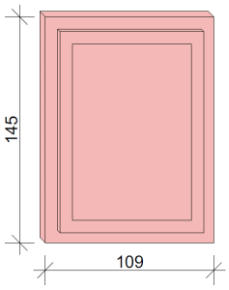
Impact of removal and impact of production of added materials:

Table 8 shows the impact of removing the old materials and Table 9 shows the impact of producing the newly added materials.

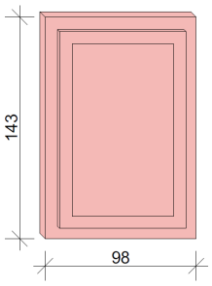
Table 8: Impact of removal (source: illustration by the author)

Window 01 (big)



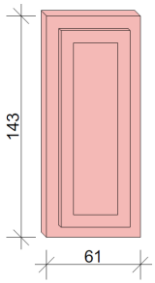
Double insulation glass			Impact per m²			Absolut Impact	
4.44	m² removed (4x1.11m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	21.22
		GWP	[kgCO₂.m⁻²]	0.33	GWP	[kg CO₂]	1.47
		AP	[kgSO₂.m⁻²]	0.00208	AP	[kg SO₂]	0.00924
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
1.88	m² removed (4x0.47m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	192.70
		GWP	[kgCO₂.m⁻²]	48.21	GWP	[kg CO₂]	90.63
		AP	[kgSO₂.m⁻²]	0.01091	AP	[kg SO₂]	0.02051
		Δ OI3	[Pkt/m²]	12.91			

Window 02 (middle)



Double insulation glass			Impact per m²			Absolut Impact	
3.84	m² removed (4x0.96m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	18.36
		GWP	[kgCO₂.m⁻²]	0.33	GWP	[kg CO₂]	1.27
		AP	[kgSO₂.m⁻²]	0.00208	AP	[kg SO₂]	0.00799
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
1.76	m² removed (4x0.44m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	180.40
		GWP	[kgCO₂.m⁻²]	48.21	GWP	[kg CO₂]	84.85
		AP	[kgSO₂.m⁻²]	0.01091	AP	[kg SO₂]	0.01920
		Δ OI3	[Pkt/m²]	12.91			

Window 03 (small)



Double insulation glass			Impact per m²			Absolut Impact	
0.50	m² removed (1x0.5m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	2.39
		GWP	[kgCO₂.m⁻²]	0.33	GWP	[kg CO₂]	0.17
		AP	[kgSO₂.m⁻²]	0.00208	AP	[kg SO₂]	0.00104
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
0.37	m² removed (1x0.37m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	37.93
		GWP	[kgCO₂.m⁻²]	48.21	GWP	[kg CO₂]	17.84
		AP	[kgSO₂.m⁻²]	0.01091	AP	[kg SO₂]	0.00404
		Δ OI3	[Pkt/m²]	12.91			

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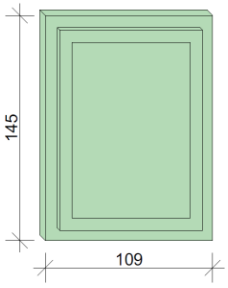
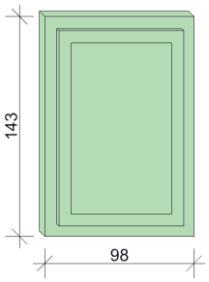
Table 9: Impact of production (source: illustration by the author)

Window 01 (big)



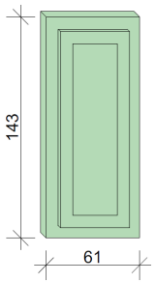
Triple glazing (MGTherm ökostar)			Impact per m²			Absolut Impact		
4.44	m² used (4x1.11m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	2370.78
		GWP	[kgCO_2.m⁻²]	40.77	GWP	[kg CO_2]	181.02
		AP	[kgSO_2.m⁻²]	0.31118	AP	[kg SO_2]	1.38164
		Δ OI3	[Pkt/m²]	66.08			
Wood frame (d = 0.1m) -spruce wood							
1.88	m² used (4x0.47m²)	PEI n.e.	[MJ.m⁻²]	1101.87	PEI n.e.	[MJ]	2071.52
		GWP	[kgCO_2.m⁻²]	-33.026	GWP	[kg CO_2]	-62.09
		AP	[kgSO_2.m⁻²]	0.30521	AP	[kg SO_2]	0.57379
		Δ OI3	[Pkt/m²]	71.92			

Window 02 (middle)



Triple glazing (MGTherm ökostar)			Impact per m²			Absolut Impact		
3.84	m² used (4x0.96m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	2050.41
		GWP	[kgCO_2.m⁻²]	40.77	GWP	[kg CO_2]	156.56
		AP	[kgSO_2.m⁻²]	0.31118	AP	[kg SO_2]	1.19493
		Δ OI3	[Pkt/m²]	66.08			
Wood frame (d = 0.1m) - spruce wood							
1.76	m² used (4x0.44m²)	PEI n.e.	[MJ.m⁻²]	1101.87	PEI n.e.	[MJ]	1939.29
		GWP	[kgCO_2.m⁻²]	-33.026	GWP	[kg CO_2]	-58.13
		AP	[kgSO_2.m⁻²]	0.30521	AP	[kg SO_2]	0.53717
		Δ OI3	[Pkt/m²]	71.92			

Window 03 (small)



Triple glazing (MGTherm ökostar)			Impact per m²			Absolut Impact		
0.50	m² used (1x0.50m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	266.98
		GWP	[kgCO_2.m⁻²]	40.77	GWP	[kg CO_2]	20.39
		AP	[kgSO_2.m⁻²]	0.31118	AP	[kg SO_2]	0.15559
		Δ OI3	[Pkt/m²]	66.08			
Wood frame (d = 0.1m) -spruce wood							
0.37	m² used (1x0.37m²)	PEI n.e.	[MJ.m⁻²]	1101.87	PEI n.e.	[MJ]	407.69
		GWP	[kgCO_2.m⁻²]	-33.026	GWP	[kg CO_2]	-12.22
		AP	[kgSO_2.m⁻²]	0.30521	AP	[kg SO_2]	0.11293
		Δ OI3	[Pkt/m²]	71.92			

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Influence of service life:

The following table (Table 10) shows the impact of all necessary material exchanges of Scenario A.1.2.

Table 10: Impact of Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO₂.m⁻²]	Production GWP [kgCO₂.m⁻²]	** GWP [kg CO₂]	Removal AP [kgSO₂.m⁻²]	Production AP [kg SO₂.m⁻²]	** AP [kg SO₂]
Glazing (windows, door)	9.20	1	7.17	533.96	4,978.40	0.49	40.77	379.59	0.0031000	0.3112	2.89
Frame (windows, door)	5.39	1	0.44	1,101.87	5,941.45	40.37	- 33.03	39.56	0.0000420	0.3052	1.65
Plaster	240.76	2	4.72	29.76	16,602.81	0.34	3.15	1,680.50	0.0000884	0.0083	4.04
Floor covering: ceramic tiles	15.01	1	4.09	649.06	9,803.78	0.30	35.83	542.31	0.0018000	0.1288	1.96
Floor covering: linoleum	36.63	2	0.24	419.50	30,750.15	14.36	9.87	1,775.09	0.0000240	0.1040	7.62
Floor covering: laminate	20.37	2	0.15	176.15	7,182.46	11.80	0.88	516.58	0.0000140	0.0355	1.45
Floor covering: textile covering	21.12	5	1.61	82.44	8,875.68	4.05	1.92	630.43	0.0025000	0.0183	2.20
Sum					**84,134.73**			**5,564.08**			**21.80**

Influence of heating demand:

This Scenario resulted in an annual heating demand of 485.89 kWh per square meter. Due that Scenario A.1.2 deals with House A the heated gross area amounts to 129.90 m². This leads to the following amount of produced CO_2 per year:

	Values per m²	Absolut values
Annual heating demand	489.89 kWh.m⁻²	63,636.71 kWh
Impact		28,000.15 kg CO_2

Summary of whole Scenario:

In Table 11 the sum for both the impact of materials and the usage regarding heating are shown.

Table 11: Sum for Scenario A.1.2 (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO_2]	AP [kg SO_2]	[kg CO_2]
Renovation measure	9,559.66	421.75	4.02	
Use (material exchages)	84,134.73	5,564.08	21.80	1,400,007.50
SUM	**93,694.39**	**5,985.83**	**25.82**	**1,400,007.50**

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3.5 Scenario A.2.1

Energy Certificate:

The Energy Certificate of House A with the conducted renovation measure A.2.1 shows that the category of the heating demand could be increased by two classes by insulating the exterior walls as well as insulating the ceiling to the unheated attic (Figure 27). The scenario ended up in a HWB of 161.72 kWh.m^{-2}.a^{-1}, which corresponds to class E.

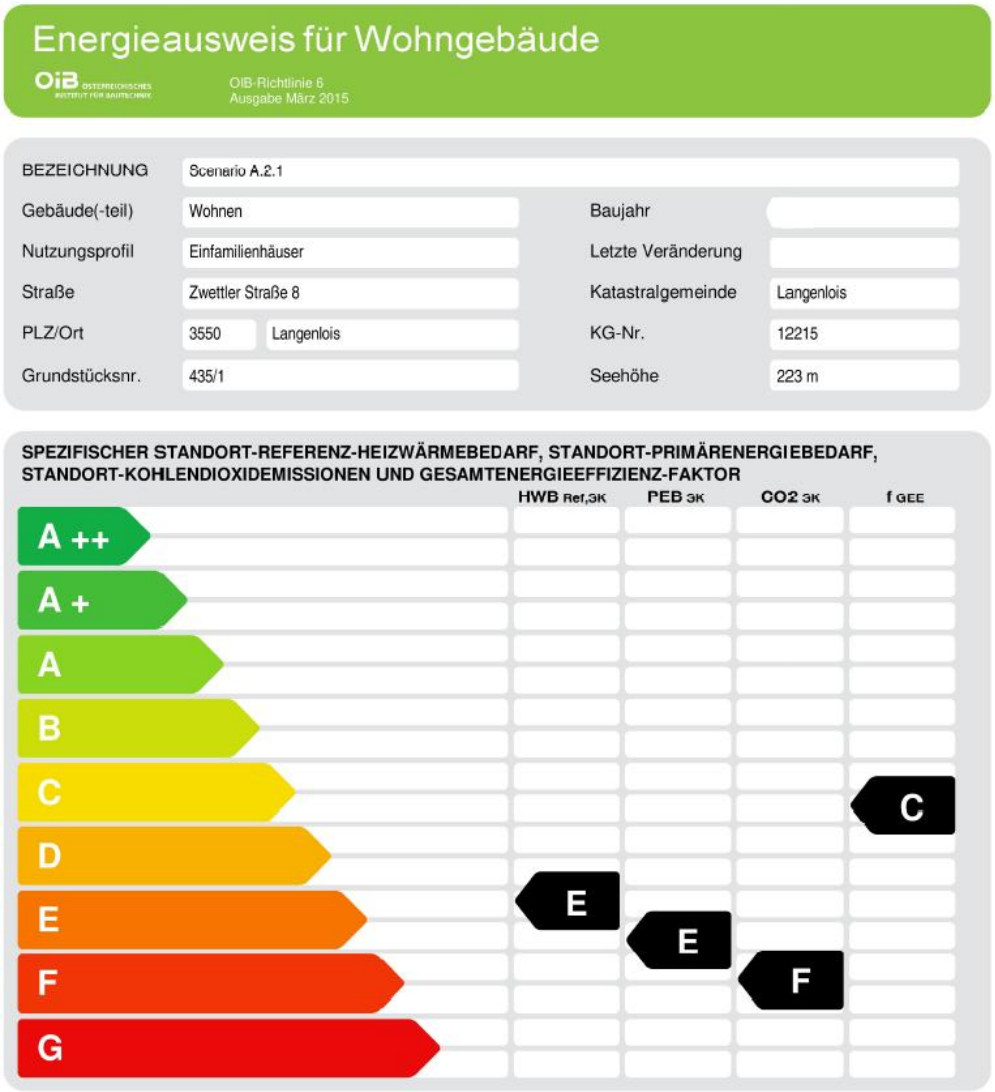

Figure 27: Energy Certificate Scenario A.2.1 (source: illustration taken from ArchiPhysik based on the author's case study buildings)

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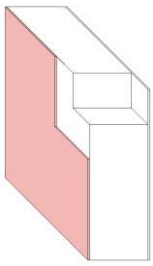
Impact of removal and impact of production of added materials:

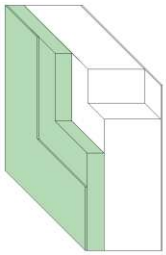
Table 12 shows those OI3 indicators that lead through the removal of the current exterior plaster. The impact per square meter of each material as well as the absolute impact of the individual material for this scenario is shown. Table 13 lists all materials with their individual environmental indicators that are newly attached to the existing supporting structure.

Table 12: Impact of removal (source: illustration by the author)



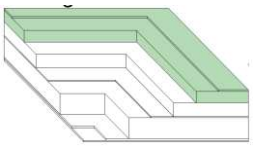
0.015 m Exterior plaster		Impact per m²		Absolut Impact	
240.76 m² removed	PEI n.e.	[MJ.m⁻²]	4.72	PEI n.e. [MJ]	1136.39
	GWP	[kgCO₂.m⁻²]	0.34	GWP [kg CO₂]	81.86
	AP	[kgSO₂.m⁻²]	0.0000884	AP [kg SO₂]	0.02128
	Δ OI3	[Pkt/m²]	0.23		

Table 13: Impact of production (source: illustration by the author)



0.015 m Heat insulation plaster		Impact per m²		Absolut Impact	
242.45 m² used	PEI n.e.	[MJ.m⁻²]	29.76	PEI n.e. [MJ]	7215.31
	GWP	[kgCO₂.m⁻²]	3.15	GWP [kg CO₂]	763.72
	AP	[kgSO₂.m⁻²]	0.0083	AP [kg SO₂]	2.0123
	Δ OI3	[Pkt/m²]	2.62		
0.15 m EPS					
242.45 m² used	PEI n.e.	[MJ.m⁻²]	234.38	PEI n.e. [MJ]	56825.43
	GWP	[kgCO₂.m⁻²]	9.88	GWP [kg CO₂]	2395.41
	AP	[kgSO₂.m⁻²]	0.0353	AP [kg SO₂]	8.5585
	Δ OI3	[Pkt/m²]	14.17		

Ceiling to unheated attic



0.1 m XPS-R		Impact per m²		Absolut Impact	
129.19 m² used	PEI n.e.	[MJ.m⁻²]	377.91	PEI n.e. [MJ]	48822.19
	GWP	[kgCO₂.m⁻²]	15.97	GWP [kg CO₂]	2063.16
	AP	[kgSO₂.m⁻²]	0.0589	AP [kg SO₂]	7.6093
	Δ OI3	[Pkt/m²]	23.11		
0.015 m Oriented strand board					
129.19 m² used	PEI n.e.	[MJ.m⁻²]	83.42	PEI n.e. [MJ]	10777.03
	GWP	[kgCO₂.m⁻²]	-11.22	GWP [kg CO₂]	-1449.51
	AP	[kgSO₂.m⁻²]	0.0204	AP [kg SO₂]	2.6355
	Δ OI3	[Pkt/m²]	3.63		

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Influence of service life:

In Table 14 the substitution during the period under consideration is shown for this Scenario. This data also applies for Scenario A.2.2.

Table 14: Substitution during the period under consideration (source: illustration by the author)

Material		Age in 2020 [years]	Period of use - according to IBO [years]	Substitution during the period under consideration
Primary construction: Supporting structure		~ 130	100	0*
Windows		29	35	2
Plaster	refurbished	0	35	1
Floor covering: ceramic tiles		28	50	1
Floor covering: linoleum		28	25	2
Floor covering: laminate		38	25	2
Floor covering: textile covering		38	10	5
Thermal insulation	refurbished	0	35	1

* It was assumed that the supporting structure could continue to exist.

Table 15 shows that during the 50-year use phase the exchange of materials lead to a non-renewable energy resource requirement (PEIn.e.) of 216,634.29 mega-joule. The category of global warming potential ended up with 15,786.33 kg CO_2 and the one for acidification potential with 42.83 kg SO_2.

Table 15: Impact of Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO_2.m⁻²]	Production GWP [kgCO_2.m⁻²]	** GWP [kg CO_2]	Removal AP [kgSO_2.m⁻²]	Production AP [kg SO_2.m⁻²]	** AP [kg SO_2]
Glazing (windows, door)	9.20	2	4.78	410.40	7,639.31	0.33	32.67	607.20	0.0020800	0.26763	4.96
Frame - plastic (windows, door)	5.39	2	102.50	3,403.67	37,796.51	48.21	151.06	2,148.13	0.0109100	0.55946	6.15
Plaster	242.45	1	4.72	29.76	8,359.68	0.34	3.15	846.15	0.0000884	0.00830	2.03
Floor covering: ceramic tiles	15.01	1	4.09	649.06	9,803.78	0.30	35.83	542.31	0.0018000	0.12880	1.96
Floor covering: linoleum	36.63	2	0.24	419.50	30,750.15	14.36	9.87	1,775.09	0.0000240	0.10400	7.62
Floor covering: laminate	20.37	2	0.15	176.15	7,182.46	11.80	0.88	516.58	0.0000140	0.03550	1.45
Floor covering: textile covering	21.12	5	1.61	82.44	8,875.68	4.05	1.92	630.43	0.0025000	0.01830	2.20
Thermal insulation - EPS	242.45	1	1.44	234.38	57,174.56	11.28	9.88	5,130.24	0.0006920	0.03530	8.73
Thermal insulation - XPS	129.19	1	1.78	377.91	49,052.15	11.82	15.97	3,590.19	0.0009390	0.05890	7.73
Sum					**216,634.29**			**15,786.33**			**42.83**

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Influence of heating demand:

With a heating demand of 161.72 kWh.m^{-2}.a^{-1} and a heated gross area of 129.90 m² the heating for this Scenario results in the following environmental impact:

	Values per m²	Absolut values
Annual heating demand	161.72 kWh.m^{-2}	21,007.43 kWh
Impact		9,243.27 kg CO_2

Summary of whole Scenario:

Table 16 sums up the results for this Scenario.

Table 16: Sum for Scenario A.2.1 (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO_2]	AP [kg SO_2]	[kg CO_2]
Renovation measure	124,776.35	3,854.63	20.84	
Use (material exchages)	216,634.29	15,786.33	42.83	462,163.50
SUM	**341,410.64**	**19,640.96**	**63.67**	**462,163.50**

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3.6 Scenario A.2.2

Energy Certificate:

The heating requirement has risen slightly compared to the version insulated with EPS and XPS. It rose from 161.72 $kWh.m^{-2}.a^{-1}$ in Scenario A.2.1 to 173.87 $kWh.m^{-2}.a^{-1}$. This is nevertheless still classified in Category E of the Energy Certificate (Figure 28).

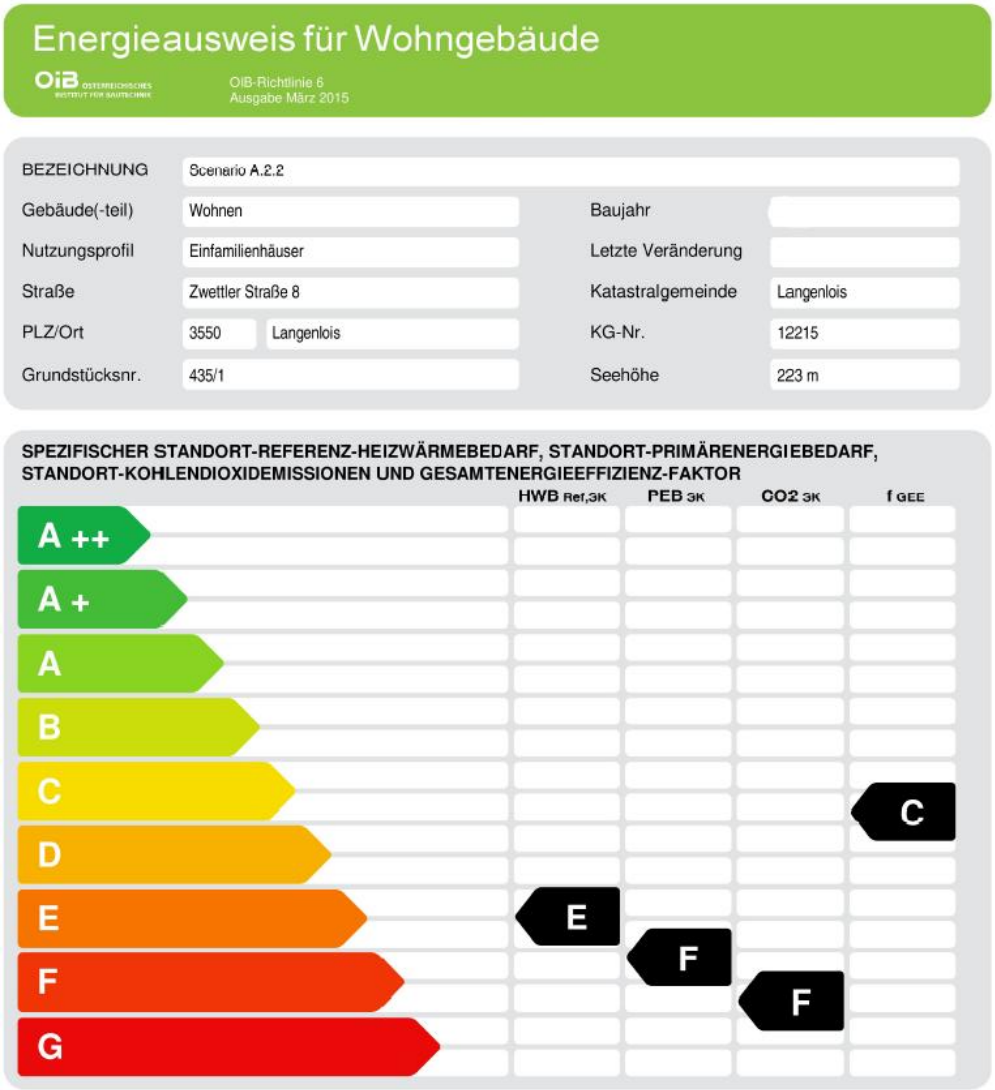

Figure 28: Energy Certificate Scenario A.2.2 (source: illustration taken from ArchiPhysik based on the author's case study buildings)

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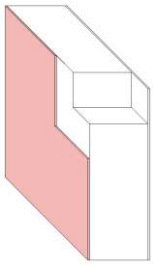
Impact of removal and impact of production of added materials:

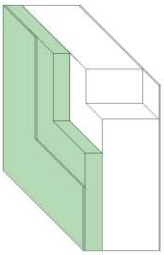
Table 17 shows the environmental impact of the removal of the current exterior plaster. Table 18 sums up all materials with their individual environmental indicators that are newly attached to the existing supporting structure.

Table 17: Impact of removal (source: illustration by the author)



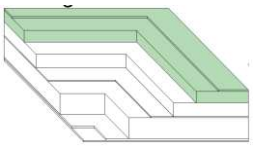
0.015 m Exterior plaster		Impact per m²			Absolut Impact		
240.76	m² removed	PEI n.e.	[MJ.m⁻²]	4.72	PEI n.e.	[MJ]	1136.39
		GWP	[kgCO₂.m⁻²]	0.34	GWP	[kg CO₂]	81.86
		AP	[kgSO₂.m⁻²]	0.0000884	AP	[kg SO₂]	0.02128
		Δ OI3	[Pkt/m²]	0.23			

Table 18: Impact of production (source: illustration by the author)



0.015 m Heat insulation plaster		Impact per m²			Absolut Impact		
242.45	m² used	PEI n.e.	[MJ.m⁻²]	29.76	PEI n.e.	[MJ]	7215.31
		GWP	[kgCO₂.m⁻²]	3.15	GWP	[kg CO₂]	763.72
		AP	[kgSO₂.m⁻²]	0.0083	AP	[kg SO₂]	2.0123
		Δ OI3	[Pkt/m²]	2.62			
0.15 m Wood fiber board							
242.45	m² used	PEI n.e.	[MJ.m⁻²]	349.87	PEI n.e.	[MJ]	84825.98
		GWP	[kgCO₂.m⁻²]	-18.09	GWP	[kg CO₂]	-4385.92
		AP	[kgSO₂.m⁻²]	0.09	AP	[kg SO₂]	21.8205
		Δ OI3	[Pkt/m²]	20.65			

Ceiling to unheated attic



0.1 m Wood fiber board		Impact per m²			Absolut Impact		
129.19	m² used	PEI n.e.	[MJ.m⁻²]	233.25	PEI n.e.	[MJ]	30133.57
		GWP	[kgCO₂.m⁻²]	-12.06	GWP	[kg CO₂]	-1558.03
		AP	[kgSO₂.m⁻²]	0.0600	AP	[kg SO₂]	7.7514
		Δ OI3	[Pkt/m²]	13.77			
0.015 m Oriented strand board							
129.19	m² used	PEI n.e.	[MJ.m⁻²]	83.42	PEI n.e.	[MJ]	10777.03
		GWP	[kgCO₂.m⁻²]	-11.22	GWP	[kg CO₂]	-1449.51
		AP	[kgSO₂.m⁻²]	0.0204	AP	[kg SO₂]	2.6355
		Δ OI3	[Pkt/m²]	3.63			

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Influence of service life:

In Table 19 the non-renewable energy resource requirement as well as the global warming potential and the acidification potential of use-phase of Scenario A.2.2 are arrayed.

Table 19: Impact of Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO₂.m⁻²]	Production GWP [kgCO₂.m⁻²]	** GWP [kg CO₂]	Removal AP [kgSO₂.m⁻²]	Production AP [kg SO₂.m⁻²]	** AP [kg SO₂]
Glazing (windows, door)	9.20	2	4.78	410.40	7,639.31	0.33	32.67	607.20	0.0020800	0.26763	4.96
Frame - plastic (windows, door)	5.39	2	102.50	3,403.67	37,796.51	48.21	151.06	2,148.13	0.0109100	0.55946	6.15
Plaster	242.45	1	4.72	29.76	8,359.68	0.34	3.15	846.15	0.0000884	0.00830	2.03
Floor covering: ceramic tiles	15.01	1	4.09	649.06	9,803.78	0.30	35.83	542.31	0.0018000	0.12880	1.96
Floor covering: linoleum	36.63	2	0.24	419.50	30,750.15	14.36	9.87	1,775.09	0.0000240	0.10400	7.62
Floor covering: laminate	20.37	2	0.15	176.15	7,182.46	11.80	0.88	516.58	0.0000140	0.03550	1.45
Floor covering: textile covering	21.12	5	1.61	82.44	8,875.68	4.05	1.92	630.43	0.0025000	0.01830	2.20
Thermal insulation - wood fiber board - wall (0,15m)	242.45	1	0.55	349.87	84,959.33	50.21	- 18.09	7,787.49	0.0000520	0.09000	21.83
Thermal insulation - wood fiber board - ceiling (0,1m)	129.19	1	0.37	233.25	30,181.37	33.47	- 12.06	2,765.96	0.0000340	0.06000	7.76
Sum					**225,548.27**			**17,619.35**			**55.96**

Influence of heating demand:

With the help of the Energy Certificate a heating requirement of 173.87 kWh per year and square meter was determined for this Scenario. This leads to the following annual influence regarding the heating demand:

	Values per m²	Absolut values
Annual heating demand	173.87 kWh.m⁻²	22,585.71 kWh
Impact		9,937.71 kg CO_2

Influence of whole Scenario:

The table below (Table 20)sums up the results for this Scenario.

Table 20: Sum for Scenario A.2.2 (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO₂]	AP [kg SO₂]	[kg CO₂]
Renovation measure	134,088.28	- 6,547.89	34.24	
Use (material exchages)	225,548.27	17,619.35	55.96	496,885.50
SUM	**359,636.55**	**11,071.46**	**90.20**	**496,885.50**

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3.7 Scenario A.3

Energy Certificate:

Figure 29 shows that various refurbishment measures carried out in this Scenario have succeeded in bringing this old existing building up to the standard of a low-energy building. The measures implemented were described in point 2.7.5.

A heating demand of HWB_{SK} = 47.18 $kWh.m^{-2}.a^{-1}$ could be achieved. This corresponds to category B.

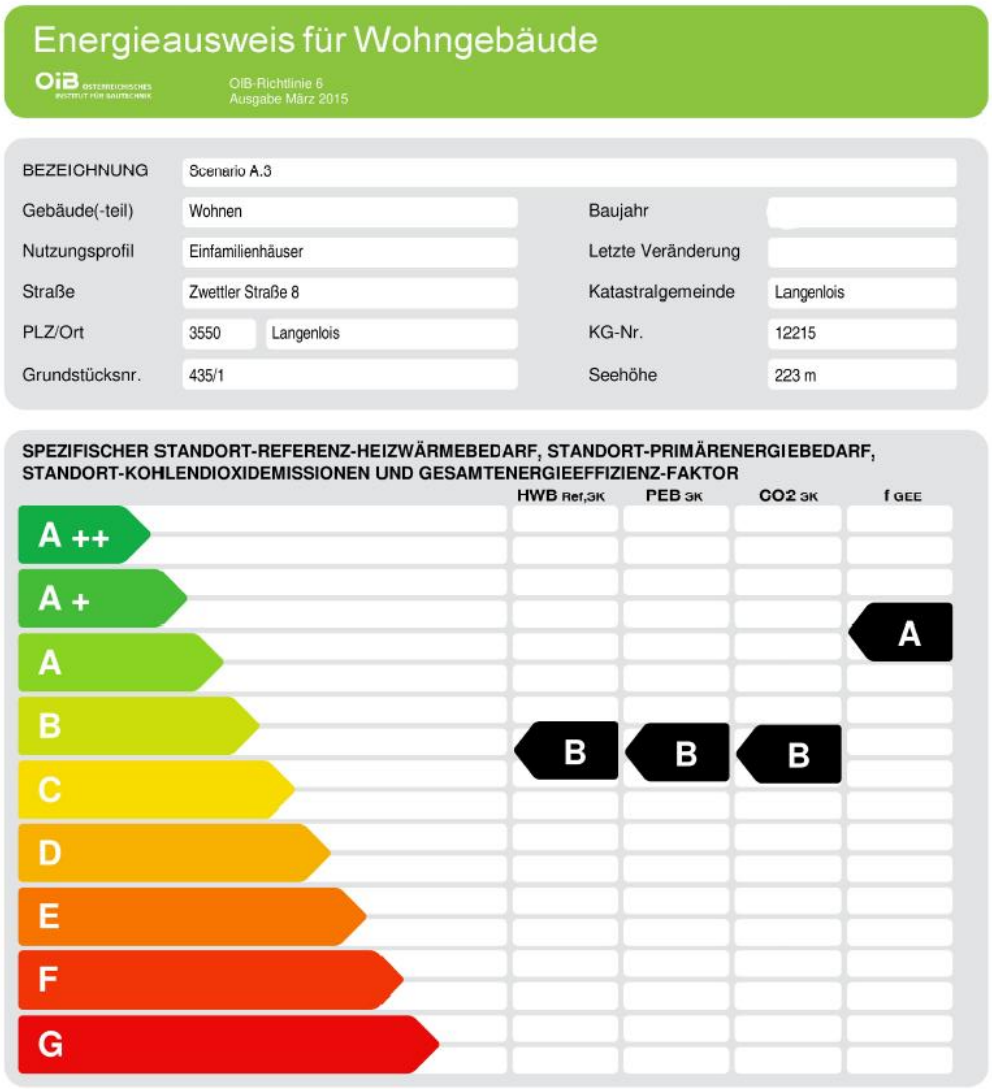

Figure 29: Energy Certificate Scenario A.3 (source: illustration taken from ArchiPhysik based on the author's case study buildings)

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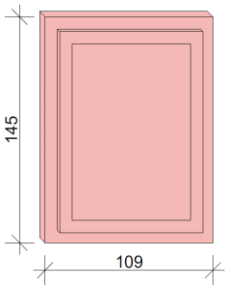
Impact of removal and impact of production of added materials:

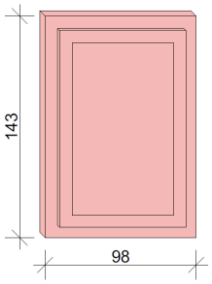
In this Scenario, the complete ceiling to the ground is removed. However, the 20 cm thick layer of gravel can then be reused for the new structure. For this reason, the gravel layer does not appear in the table (Table 21, Table 22) for removed materials. In the new structure, a 50 cm thick layer of gravel is placed. Since 20 cm can be reused, only a 30 cm thick layer is required.

Table 21: Impact of removal (Part 1) (source: illustration by the author)



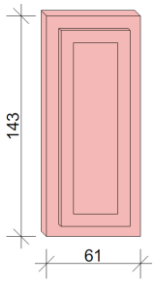
Double insulation glass		Impact per m²			Absolut Impact		
4.44	m² removed (4x1.11m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	21.22
		GWP	[kgCO_2.m⁻²]	0.33	GWP	[kg CO_2]	1.47
		AP	[kgSO_2.m⁻²]	0.0021	AP	[kg SO_2]	0.00924
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
1.88	m² removed (4x0.47m²)	PEI n.e.	[MJ.m⁻²]	102.50	PEI n.e.	[MJ]	192.70
		GWP	[kgCO_2.m⁻²]	48.21	GWP	[kg CO_2]	90.63
		AP	[kgSO_2.m⁻²]	0.0109	AP	[kg SO_2]	0.02051
		Δ OI3	[Pkt/m²]	12.91			

Window 02 (middle)



Double insulation glass		Impact per m²			Absolut Impact		
3.84	m² removed (4x0.96m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	18.36
		GWP	[kgCO_2.m⁻²]	0.33	GWP	[kg CO_2]	1.27
		AP	[kgSO_2.m⁻²]	0.0021	AP	[kg SO_2]	0.00799
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
1.76	m² removed (4x0.44m²)	PEI n.e.	[MJ.m⁻²]	102.50	PEI n.e.	[MJ]	180.40
		GWP	[kgCO_2.m⁻²]	48.21	GWP	[kg CO_2]	84.85
		AP	[kgSO_2.m⁻²]	0.0109	AP	[kg SO_2]	0.01920
		Δ OI3	[Pkt/m²]	12.91			

Window 03 (small)



Double insulation glass		Impact per m²			Absolut Impact		
0.50	m² removed (1x0.5m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	2.39
		GWP	[kgCO_2.m⁻²]	0.33	GWP	[kg CO_2]	0.17
		AP	[kgSO_2.m⁻²]	0.0021	AP	[kg SO_2]	0.00104
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
0.37	m² removed (1x0.37m²)	PEI n.e.	[MJ.m⁻²]	102.50	PEI n.e.	[MJ]	37.93
		GWP	[kgCO_2.m⁻²]	48.21	GWP	[kg CO_2]	17.84
		AP	[kgSO_2.m⁻²]	0.0109	AP	[kg SO_2]	0.00404
		Δ OI3	[Pkt/m²]	12.91			

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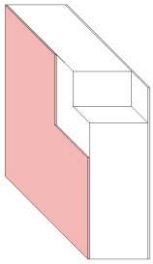
Table 22: Impact of removal (Part 2) (source: illustration by the author)

Entrance door

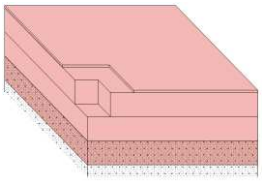
Double insulation glass		Impact per m²			Absolut Impact		
0.42	m² removed (1x0.42m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	2.01
		GWP	[kgCO_2.m⁻²]	0.33	GWP	[kg CO_2]	0.14
		AP	[kgSO_2.m⁻²]	0.0021	AP	[kg SO_2]	0.00087
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
1.38	m² removed (1x1.38m²)	PEI n.e.	[MJ.m⁻²]	102.50	PEI n.e.	[MJ]	141.45
		GWP	[kgCO_2.m⁻²]	48.21	GWP	[kg CO_2]	66.53
		AP	[kgSO_2.m⁻²]	0.0109	AP	[kg SO_2]	0.01506
		Δ OI3	[Pkt/m²]	12.91			

Exterior walls



0.015 m Exterior plaster		Impact per m²			Absolut Impact		
240.76	m² removed	PEI n.e.	[MJ.m⁻²]	4.72	PEI n.e.	[MJ]	1136.39
		GWP	[kgCO_2.m⁻²]	0.34	GWP	[kg CO_2]	81.86
		AP	[kgSO_2.m⁻²]	0.000088	AP	[kg SO_2]	0.02128
		Δ OI3	[Pkt/m²]	0.23			

Ceilings to ground



0.2 m Concrete C20/25		Impact per m²			Absolut Impact		
93.13	m² removed	PEI n.e.	[MJ.m⁻²]	78.70	PEI n.e.	[MJ]	7329.33
		GWP	[kgCO_2.m⁻²]	6.01	GWP	[kg CO_2]	559.71
		AP	[kgSO_2.m⁻²]	0.0113	AP	[kg SO_2]	1.05237
		Δ OI3	[Pkt/m²]	5.13			
0.02m Tiles							
15.01	m² removed	PEI n.e.	[MJ.m⁻²]	4.09	PEI n.e.	[MJ]	61.39
		GWP	[kgCO_2.m⁻²]	0.30	GWP	[kg CO_2]	4.50
		AP	[kgSO_2.m⁻²]	0.0018	AP	[kg SO_2]	0.02702
		Δ OI3	[Pkt/m²]	0.43			
0.01 m Linoleum							
36.63	m² removed	PEI n.e.	[MJ.m⁻²]	0.24	PEI n.e.	[MJ]	8.79
		GWP	[kgCO_2.m⁻²]	14.36	GWP	[kg CO_2]	526.01
		AP	[kgSO_2.m⁻²]	0.000024	AP	[kg SO_2]	0.00088
		Δ OI3	[Pkt/m²]	2.40			
0.01 m Carpet							
21.12	m² removed	PEI n.e.	[MJ.m⁻²]	1.61	PEI n.e.	[MJ]	34.00
		GWP	[kgCO_2.m⁻²]	4.05	GWP	[kg CO_2]	85.54
		AP	[kgSO_2.m⁻²]	0.0025	AP	[kg SO_2]	0.05280
		Δ OI3	[Pkt/m²]	1.06			
0.01 m Laminate							
20.37	m² removed	PEI n.e.	[MJ.m⁻²]	0.15	PEI n.e.	[MJ]	3.06
		GWP	[kgCO_2.m⁻²]	11.80	GWP	[kg CO_2]	240.37
		AP	[kgSO_2.m⁻²]	0.000014	AP	[kg SO_2]	0.00029
		Δ OI3	[Pkt/m²]	1.97			

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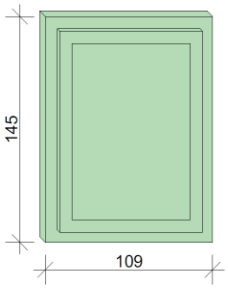
In Table 23, Table 24 and Table 25 the impact of production is shown.

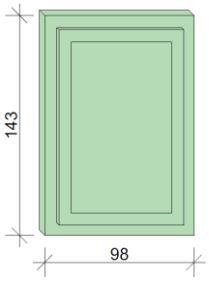
Table 23: Impact of production (Part 1) (source: illustration by the author)

Window 01 (big)



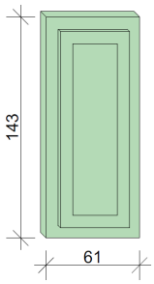
Triple glazing				Impact per m²		Absolut Impact		
4.44	m² used (4x1.11m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	2370.78
		GWP	[$kgCO_2.m^{-2}$]	40.77	GWP	[kg CO_2]	181.02
		AP	[$kgSO_2.m^{-2}$]	0.3112	AP	[kg SO_2]	1.38164
		Δ OI3	[Pkt/m²]	66.08			
Wood frame (d = 0.1m) - spruce wood							
1.88	m² used (4x0.47m²)	PEI n.e.	[MJ.m⁻²]	1101.87	PEI n.e.	[MJ]	2071.52
		GWP	[$kgCO_2.m^{-2}$]	-33.03	GWP	[kg CO_2]	-62.09
		AP	[$kgSO_2.m^{-2}$]	0.3052	AP	[kg SO_2]	0.57379
		Δ OI3	[Pkt/m²]	71.92			

Window 02 (middle)



Triple glazing				Impact per m²		Absolut Impact	
3.84	m² used (4x0.96m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	2050.41
		GWP	[$kgCO_2.m^{-2}$]	40.77	GWP	[kg CO_2]	156.56
		AP	[$kgSO_2.m^{-2}$]	0.3112	AP	[kg SO_2]	1.19493
		Δ OI3	[Pkt/m²]	66.08			
Wood frame (d = 0.1m) -spruce wood							
1.76	m² used (4x0.44m²)	PEI n.e.	[MJ.m⁻²]	1101.87	PEI n.e.	[MJ]	1939.29
		GWP	[$kgCO_2.m^{-2}$]	-33.03	GWP	[kg CO_2]	-58.13
		AP	[$kgSO_2.m^{-2}$]	0.3052	AP	[kg SO_2]	0.53717
		Δ OI3	[Pkt/m²]	71.92			

Window 03 (small)



Triple glazing				Impact per m²		Absolut Impact	
0.50	m² used (1x0.50m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	266.98
		GWP	[$kgCO_2.m^{-2}$]	40.77	GWP	[kg CO_2]	20.39
		AP	[$kgSO_2.m^{-2}$]	0.3112	AP	[kg SO_2]	0.15559
		Δ OI3	[Pkt/m²]	66.08			
Wood frame (d = 0.1m) - spruce wood							
0.37	m² used (1x0.37m²)	PEI n.e.	[MJ.m⁻²]	1101.87	PEI n.e.	[MJ]	407.69
		GWP	[$kgCO_2.m^{-2}$]	-33.03	GWP	[kg CO_2]	-12.22
		AP	[$kgSO_2.m^{-2}$]	0.3052	AP	[kg SO_2]	0.11293
		Δ OI3	[Pkt/m²]	71.92			

Entrance door

Triple glazing				Impact per m²		Absolut Impact	
0.42	m² used (1x0.42m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	224.26
		GWP	[$kgCO_2.m^{-2}$]	40.77	GWP	[kg CO_2]	17.12
		AP	[$kgSO_2.m^{-2}$]	0.3112	AP	[kg SO_2]	0.13070
		Δ OI3	[Pkt/m²]	66.08			
Wood frame (d = 0.1m) - spruce wood							
1.38	m² used (1x1.38m²)	PEI n.e.	[MJ.m⁻²]	1101.87	PEI n.e.	[MJ]	1520.58
		GWP	[$kgCO_2.m^{-2}$]	-33.03	GWP	[kg CO_2]	-45.58
		AP	[$kgSO_2.m^{-2}$]	0.3052	AP	[kg SO_2]	0.42119
		Δ OI3	[Pkt/m²]	71.92			

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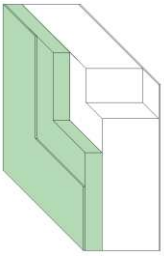
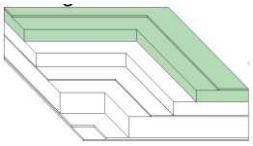
Table 24: Impact of production (Part 2) (source: illustration by the author)

Exterior walls



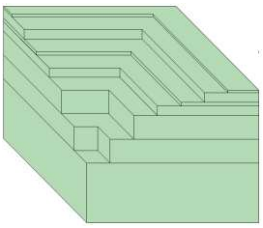
0.015 m Heat insulation plaster		Impact per m²			Absolut Impact		
243.18	m² used	PEI n.e.	[MJ.m⁻²]	29.76	PEI n.e.	[MJ]	7237.04
		GWP	[kgCO_2.m⁻²]	3.15	GWP	[kg CO_2]	766.02
		AP	[kgSO_2.m⁻²]	0.0083	AP	[kg SO_2]	2.0184
		Δ OI3	[Pkt/m²]	2.62			
0.2 m EPS							
243.18	m² used	PEI n.e.	[MJ.m⁻²]	312.50	PEI n.e.	[MJ]	75993.75
		GWP	[kgCO_2.m⁻²]	13.17	GWP	[kg CO_2]	3202.68
		AP	[kgSO_2.m⁻²]	0.0470	AP	[kg SO_2]	11.4295
		Δ OI3	[Pkt/m²]	18.88			

Ceiling to unheated attic



0.2 m XPS-R		Impact per m²			Absolut Impact		
129.19	m² used	PEI n.e.	[MJ.m⁻²]	755.82	PEI n.e.	[MJ]	97644.39
		GWP	[kgCO_2.m⁻²]	31.95	GWP	[kg CO_2]	4127.62
		AP	[kgSO_2.m⁻²]	0.1178	AP	[kg SO_2]	15.2186
		Δ OI3	[Pkt/m²]	46.23			
0.015 m Oriented strand board							
129.19	m² used	PEI n.e.	[MJ.m⁻²]	83.42	PEI n.e.	[MJ]	10777.03
		GWP	[kgCO_2.m⁻²]	-11.22	GWP	[kg CO_2]	-1449.51
		AP	[kgSO_2.m⁻²]	0.0204	AP	[kg SO_2]	2.6355
		Δ OI3	[Pkt/m²]	3.63			

Ceilings to ground



0.3 m Gravel (0.2 m can be reused)		Impact per m²			Absolut Impact		
93.13	m² used	PEI n.e.	[MJ.m⁻²]	43.20	PEI n.e.	[MJ]	4023.22
		GWP	[kgCO_2.m⁻²]	2.16	GWP	[kg CO_2]	201.16
		AP	[kgSO_2.m⁻²]	0.0000	AP	[kg SO_2]	0.00000
		Δ OI3	[Pkt/m²]	1.80			
0.2 m XPS-G 50							
93.13	m² used	PEI n.e.	[MJ.m⁻²]	711.09	PEI n.e.	[MJ]	66223.81
		GWP	[kgCO_2.m⁻²]	31.95	GWP	[kg CO_2]	2975.50
		AP	[kgSO_2.m⁻²]	0.1180	AP	[kg SO_2]	10.98934
		Δ OI3	[Pkt/m²]	44.76			
0.2 m Concrete							
93.13	m² used	PEI n.e.	[MJ.m⁻²]	504.00	PEI n.e.	[MJ]	46937.52
		GWP	[kgCO_2.m⁻²]	66.72	GWP	[kg CO_2]	6213.63
		AP	[kgSO_2.m⁻²]	0.1440	AP	[kg SO_2]	13.41072
		Δ OI3	[Pkt/m²]	47.12			
0.001 m Sealing							
93.13	m² used	PEI n.e.	[MJ.m⁻²]	8.17	PEI n.e.	[MJ]	760.87
		GWP	[kgCO_2.m⁻²]	0.23	GWP	[kg CO_2]	21.42
		AP	[kgSO_2.m⁻²]	0.0013	AP	[kg SO_2]	0.12107
		Δ OI3	[Pkt/m²]	0.48			
0.08 m EPS granulate levelling compound							
93.13	m² used	PEI n.e.	[MJ.m⁻²]	113.47	PEI n.e.	[MJ]	10567.46
		GWP	[kgCO_2.m⁻²]	8.65	GWP	[kg CO_2]	805.57
		AP	[kgSO_2.m⁻²]	0.0204	AP	[kg SO_2]	1.89985
		Δ OI3	[Pkt/m²]	7.94			

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Table 25: Impact of production (Part 3) (source: illustration by the author)

0.03 m Footfall sound insulation							
93.13	m² used	PEI n.e.	[MJ.m⁻²]	32.63	PEI n.e.	[MJ]	3038.83
		GWP	[kgCO_2.m⁻²]	1.37	GWP	[kg CO_2]	127.59
		AP	[kgSO_2.m⁻²]	0.0049	AP	[kg SO_2]	0.45634
		Δ OI3	[Pkt/m²]	1.97			
0.001 m PE-foil							
93.13	m² used	PEI n.e.	[MJ.m⁻²]	90.07	PEI n.e.	[MJ]	8388.22
		GWP	[kgCO_2.m⁻²]	4.96	GWP	[kg CO_2]	461.92
		AP	[kgSO_2.m⁻²]	0.0235	AP	[kg SO_2]	2.18856
		Δ OI3	[Pkt/m²]	6.96			
0.08 m Screed							
93.13	m² used	PEI n.e.	[MJ.m⁻²]	140.80	PEI n.e.	[MJ]	13112.70
		GWP	[kgCO_2.m⁻²]	15.36	GWP	[kg CO_2]	1430.48
		AP	[kgSO_2.m⁻²]	0.0384	AP	[kg SO_2]	3.57619
		Δ OI3	[Pkt/m²]	12.37			
0.02 m Tiles							
15.01	m² used	PEI n.e.	[MJ.m⁻²]	649.06	PEI n.e.	[MJ]	9742.39
		GWP	[kgCO_2.m⁻²]	35.83	GWP	[kg CO_2]	537.81
		AP	[kgSO_2.m⁻²]	0.1288	AP	[kg SO_2]	1.93329
		Δ OI3	[Pkt/m²]	44.78			
0.01 m Linoleum							
36.63	m² used	PEI n.e.	[MJ.m⁻²]	419.50	PEI n.e.	[MJ]	15366.29
		GWP	[kgCO_2.m⁻²]	9.87	GWP	[kg CO_2]	361.54
		AP	[kgSO_2.m⁻²]	0.1040	AP	[kg SO_2]	3.80952
		Δ OI3	[Pkt/m²]	29.50			
0.01 m Carpet							
21.12	m² used	PEI n.e.	[MJ.m⁻²]	82.44	PEI n.e.	[MJ]	1741.13
		GWP	[kgCO_2.m⁻²]	1.92	GWP	[kg CO_2]	40.55
		AP	[kgSO_2.m⁻²]	0.0183	AP	[kg SO_2]	0.38650
		Δ OI3	[Pkt/m²]	5.51			
0.01 m Laminate							
20.37	m² used	PEI n.e.	[MJ.m⁻²]	176.15	PEI n.e.	[MJ]	3588.18
		GWP	[kgCO_2.m⁻²]	0.88	GWP	[kg CO_2]	17.93
		AP	[kgSO_2.m⁻²]	0.0355	AP	[kg SO_2]	0.72314
		Δ OI3	[Pkt/m²]	10.75			

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Influence of service life:

Table 26 shows how often the materials of this Scenario must be exchanged during the period under consideration.

Table 26: Substitution during the period under consderation (source: illustration by the author)

Material		Age in 2020 [years]	Period of use - according to IBO [years]	Substitution during the period under consideration
Primary construction: Supporting structure		~ 130	100	0*
Windows	refurbished	0	35	1
Plaster	refurbished	0	35	1
Floor covering: ceramic tiles	refurbished	0	50	0
Floor covering: linoleum	refurbished	0	25	1
Floor covering: laminate	refurbished	0	25	1
Floor covering: textile covering	refurbished	0	10	4
Thermal insulation	refurbished	0	35	1

* It was assumed that the supporting structure could continue to exist.

In the following table (Table 27) the results for the use phase are listed.

Table 27: Impact of Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO_2.m⁻²]	Production GWP [kgCO_2.m⁻²]	** GWP [kg CO_2]	Removal AP [kgSO_2.m⁻²]	Production AP [kg SO_2.m⁻²]	** AP [kg SO_2]
Glazing (windows, door)	9.20	1	7.17	533.96	4,978.40	0.49	40.77	379.59	0.0031000	0.3112	2.89
Frame - plastic (windows, door)	5.39	1	0.44	1,101.87	5,941.45	40.37	- 33.03	39.56	0.0000420	0.3052	1.65
Plaster	242.45	1	4.72	29.76	8,359.68	0.34	3.15	846.15	0.0000884	0.0083	2.03
Floor covering: ceramic tiles	15.01	0	4.09	649.06	-	0.30	35.83	-	0.0018000	0.1288	0.00
Floor covering: linoleum	36.63	1	0.24	419.50	15,375.08	14.36	9.87	887.54	0.0000240	0.1040	3.81
Floor covering: laminate	20.37	1	0.15	176.15	3,591.23	11.80	0.88	258.29	0.0000140	0.0355	0.72
Floor covering: textile covering	21.12	4	1.61	82.44	7,100.54	4.05	1.92	504.35	0.0025000	0.0183	1.76
Thermal insulation - EPS (d=0,2m)	243.18	1	1.92	312.50	76,460.66	15.04	13.17	6,860.11	0.0009220	0.0470	11.65
Thermal insulation - XPS-R (d=0,2m)	129.19	1	3.55	755.82	98,103.01	23.64	31.95	7,181.67	0.0018770	0.1178	15.46
Sum					**219,910.04**			**16,957.27**			**39.98**

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Influence of heating demand:

The achieved heating requirement of HWB_{SK} = 47.18 kWh.m^{-2}.a^{-1} leads to following impact for heating per year:

	Values per m²	Absolut values
Annual heating demand	47.18 kWh.m^{-2}	6,128.68 kWh
Impact		2,696.62 kg CO_2

Influence of whole Scenario:

In Table 28 the sum for the whole Scenario is shown.

Table 28: Sum for Scenario A.3 (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO_2]	AP [kg SO_2]	[kg CO_2]
Renovation measure	395,163.74	21,799.85	76.54	
Use (material exchages)	219,910.04	16,957.27	39.98	134,831.00
SUM	**615,073.78**	**38,757.12**	**116.52**	**134,831.00**

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3.8 House B

Energy Certificate:

House B performs better than House A, but also here improvements can be made. In terms of heating demand (HWB_{SK}), this building is with 185.12 $kWh.m^{-2}.a^{-1}$ classified in category E (Figure 30).

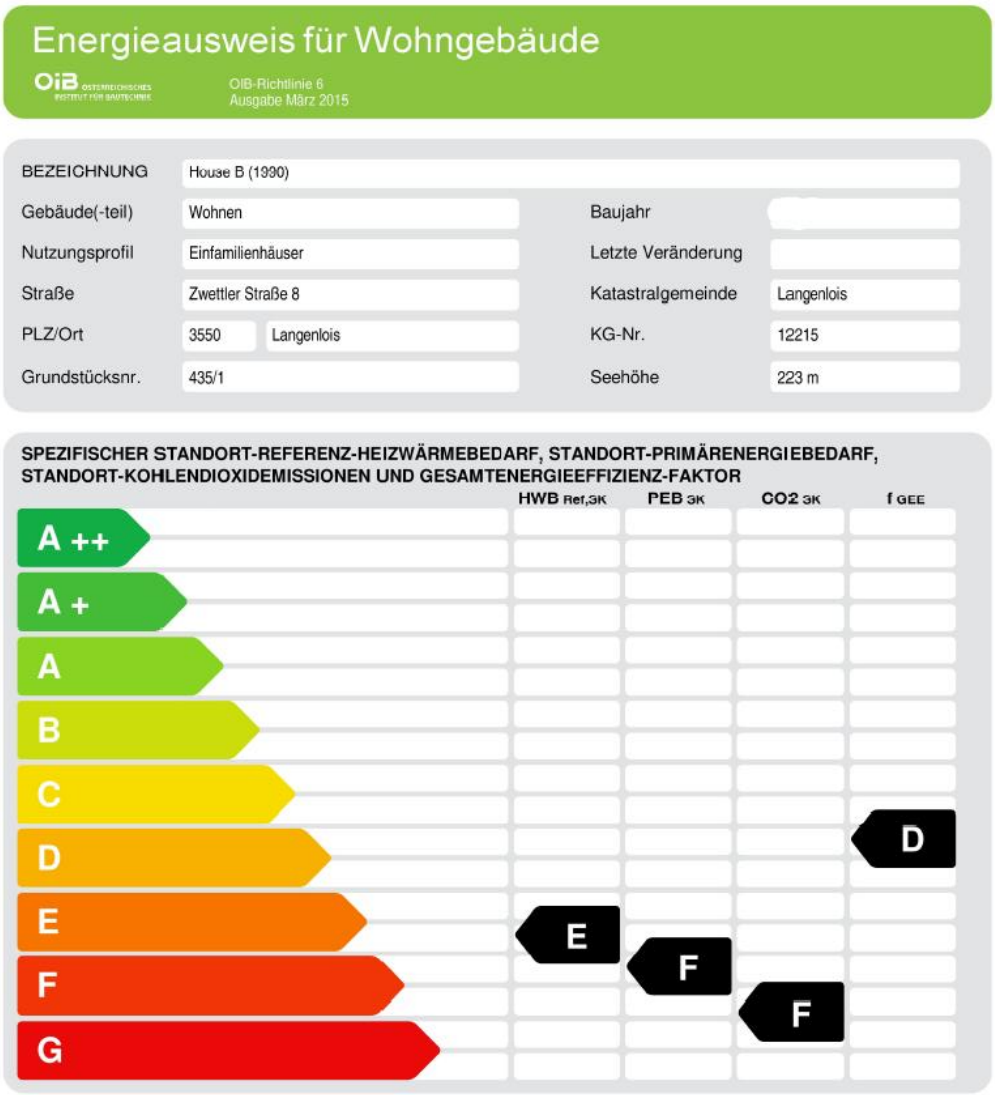

Figure 30: Energy Certificate House B (source: illustration taken from ArchiPhysik based on the author's case study buildings)

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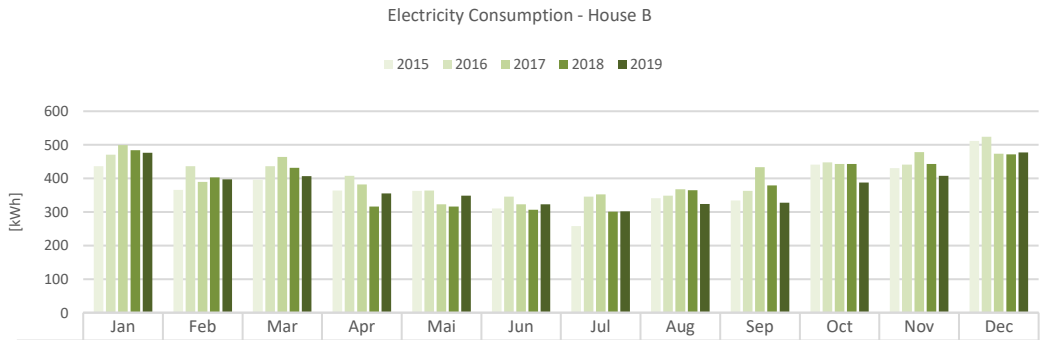
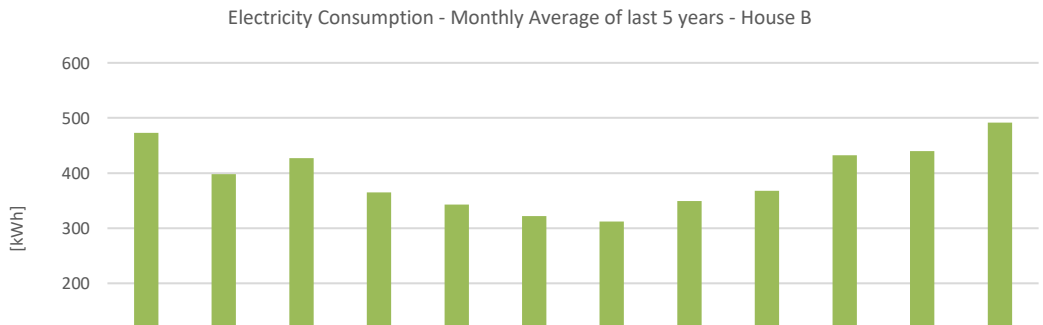
Current Electricity-, Gas- and Water Consumption:

The following Figures (Figure 31, Figure 32, Figure 33, Figure 34, Figure 35, and Figure 36) show the current gas consumption, electricity consumption and water consumption of House B. The values shown represent the monthly consumptions of the last five years (2019-2015).



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	436.1	365.5	396.4	364.0	363.1	310.0	258.3	340.6	333.9	441.4	430.3	511.2
2016	470.4	436.4	436.0	407.6	363.5	345.9	345.8	348.8	362.7	447.6	440.7	524.3
2017	499.0	389.3	463.7	381.5	322.8	322.8	352.4	367.4	433.9	443.4	477.9	473.6
2018	484.0	402.7	432.0	316.3	316.4	306.9	301.3	364.4	379.1	442.6	442.6	472.0
2019	476.4	397.4	407.1	355.6	348.5	322.5	301.9	324.2	327.9	387.3	407.3	477.0

Figure 31: Electricity Consumption House B (2015-2019) (source: illustration by the author)



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	473.2	398.3	427.0	365.0	342.9	321.6	311.9	349.1	367.5	432.5	439.8	491.6

Figure 32: Monthly Average Electricity Consumption of last 5 years - House B (2015-2019) (source: illustration by the author)

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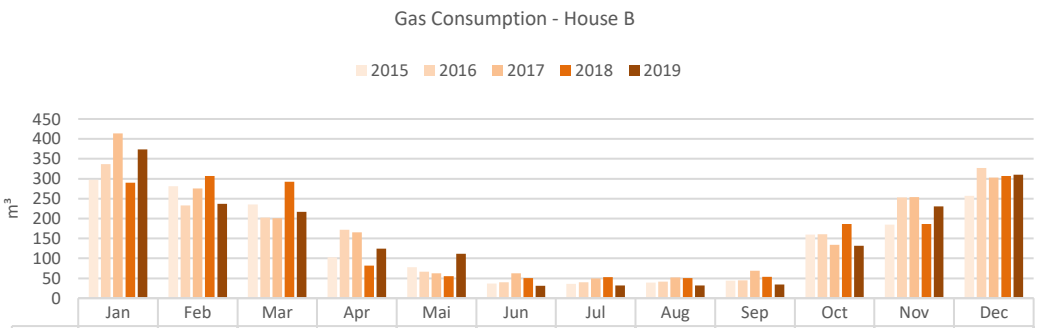
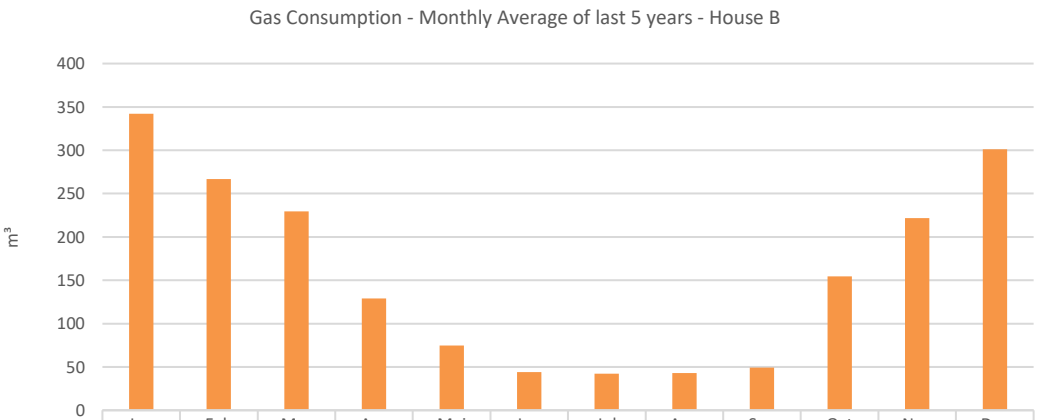


	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	297.0	281.3	235.7	102.3	77.9	37.0	35.9	38.9	43.8	159.9	184.9	257.2
2016	336.6	232.7	202.4	171.7	66.9	40.0	39.9	41.6	45.0	160.4	253.4	327.2
2017	413.5	275.2	200.5	165.1	62.5	62.4	49.6	51.8	69.0	133.7	254.2	302.9
2018	289.6	306.8	292.4	81.4	55.1	50.3	53.2	50.1	53.6	185.9	186.0	307.2
2019	373.5	237.1	216.7	124.7	111.4	31.1	31.8	32.2	34.1	131.8	230.3	310.2

Figure 33: Gas Consumption House B (2015-2019) (source: illustration by the author)



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	342.0	266.6	229.5	129.0	74.8	44.2	42.1	42.9	49.1	154.3	221.8	300.9

Figure 34: Monthly Average Gas Consumption of last 5 years - House B (2015-2019) (source: illustration by the author)

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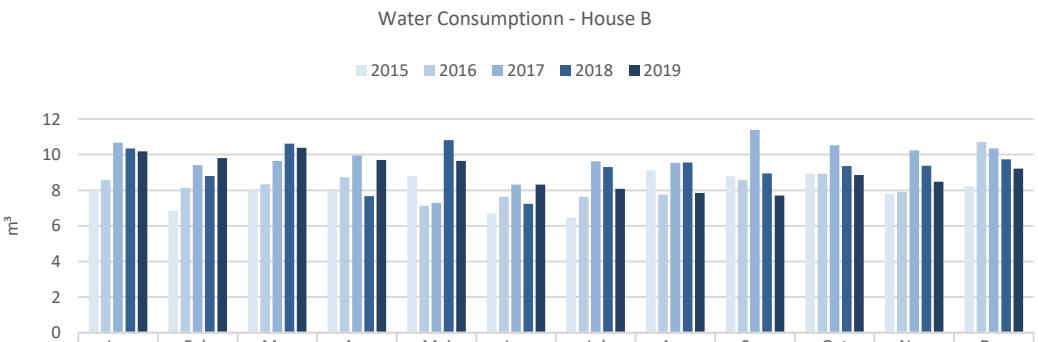
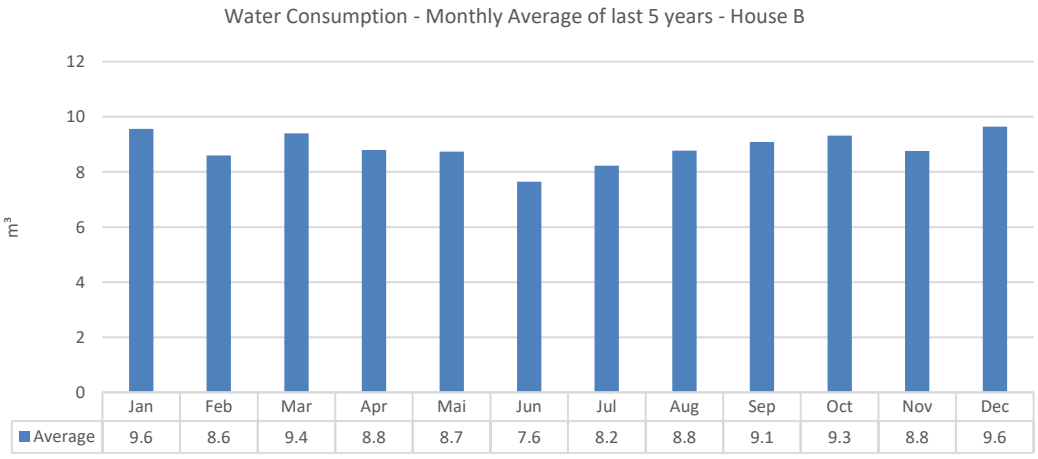


	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	8.0	6.8	8.0	8.0	8.8	6.7	6.5	9.1	8.8	8.9	7.8	8.2
2016	8.6	8.1	8.3	8.7	7.1	7.6	7.6	7.8	8.6	8.9	7.9	10.7
2017	10.7	9.4	9.6	9.9	7.3	8.3	9.6	9.5	11.4	10.5	10.2	10.3
2018	10.3	8.8	10.6	7.7	10.8	7.2	9.3	9.6	8.9	9.4	9.4	9.7
2019	10.2	9.8	10.4	9.7	9.6	8.3	8.1	7.8	7.7	8.9	8.5	9.2

Figure 35: Water Consumption House B (2015-2019) (source: illustration by the author)



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	9.6	8.6	9.4	8.8	8.7	7.6	8.2	8.8	9.1	9.3	8.8	9.6

Figure 36: Monthly Average Water Consumption of last 5 years - House B (2015-2019) (source: illustration by the author)

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3.9 Scenario B.1.1

Energy Certificate:

The rehabilitation measures of Scenario B.1.1 result in a heating demand of HWB_{SK} = 170.53 kWh.m^{-2}.a^{-1}. This corresponds to category E of the Energy Certificate, as Figure 37 represents.

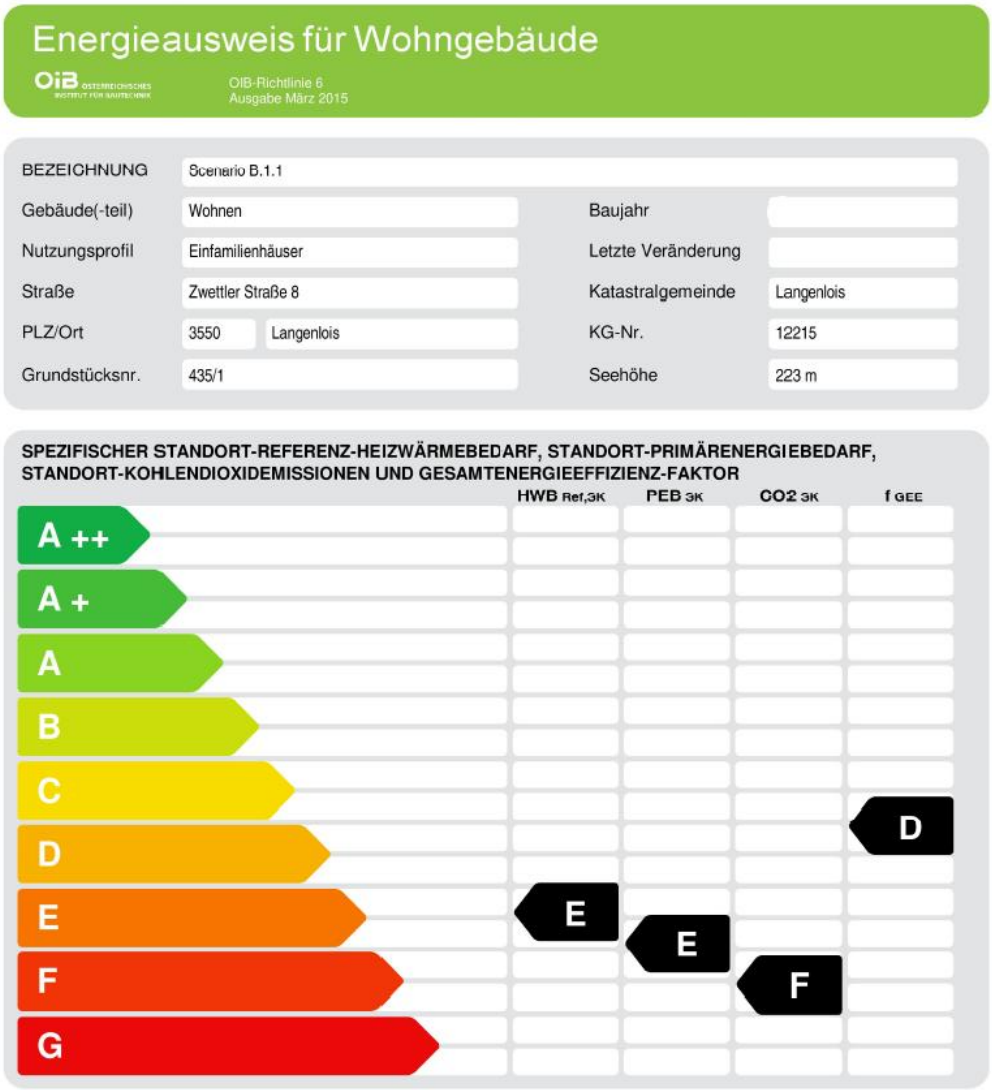

Figure 37: Energy Certificate Scenario B.1.1 (source: illustration taken from ArchiPhysik based on the author's case study buildings)

Impact of removal and impact of production of added materials:

Table 29 shows the impact of removing the old materials. Table 30 sums up all newly added components and their materials as well as the impact on the environment represented with the three OI3 indicators.

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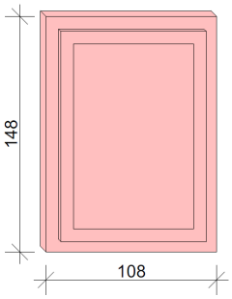
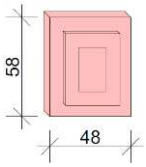
Table 29: Impact of removal (source: illustration by the author)



Double insulation glass			Impact per m²			Absolut Impact		
11.30	m² removed (10x1.13m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	54.01
		GWP	[kgCO₂.m⁻²]	0.33	GWP	[kg CO₂]	3.73
		AP	[kgSO₂.m⁻²]	0.00208	AP	[kg SO₂]	0.02350
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
4.70	m² removed (10x0.47m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	481.75
		GWP	[kgCO₂.m⁻²]	48.21	GWP	[kg CO₂]	226.59
		AP	[kgSO₂.m⁻²]	0.01091	AP	[kg SO₂]	0.05128
		Δ OI3	[Pkt/m²]	12.91			

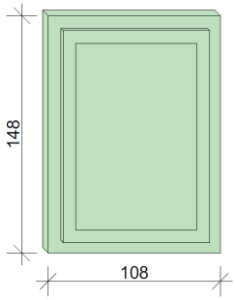
Window 02 (small)



Double insulation glass			Impact per m²			Absolut Impact		
0.22	m² removed (2x0.11m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	1.05
		GWP	[kgCO₂.m⁻²]	0.33	GWP	[kg CO₂]	0.07
		AP	[kgSO₂.m⁻²]	0.00208	AP	[kg SO₂]	0.00046
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
0.34	m² removed (2x0.17m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	34.85
		GWP	[kgCO₂.m⁻²]	48.21	GWP	[kg CO₂]	16.39
		AP	[kgSO₂.m⁻²]	0.01091	AP	[kg SO₂]	0.00371
		Δ OI3	[Pkt/m²]	12.91			

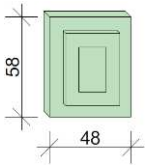
Table 30: Impact of production (source: illustration by the author)

Window 01 (big)



Triple heat protection glass			Impact per m²			Absolut Impact		
11.30	m² used (10x1.13m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	6033.75
		GWP	[kgCO₂.m⁻²]	40.77	GWP	[kg CO₂]	460.70
		AP	[kgSO₂.m⁻²]	0.31118	AP	[kg SO₂]	3.51633
		Δ OI3	[Pkt/m²]	66.08			
Wood-aluminium frame (d = 0.1m) - spruce wood							
4.70	m² used (10x0.47m²)	PEI n.e.	[MJ.m⁻²]	1741.86	PEI n.e.	[MJ]	8186.74
		GWP	[kgCO₂.m⁻²]	-9.89	GWP	[kg CO₂]	-46.48
		AP	[kgSO₂.m⁻²]	0.5226	AP	[kg SO₂]	2.45622
		Δ OI3	[Pkt/m²]	126.09			

Window 03 (small)



Triple heat protection glass			Impact per m²			Absolut Impact		
0.22	m² used (2x0.11m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	117.47
		GWP	[kgCO₂.m⁻²]	40.77	GWP	[kg CO₂]	8.97
		AP	[kgSO₂.m⁻²]	0.31118	AP	[kg SO₂]	0.06846
		Δ OI3	[Pkt/m²]	66.08			
Wood-aluminium frame (d = 0.1m) - spruce wood							
0.34	m² used (2x0.17m²)	PEI n.e.	[MJ.m⁻²]	1741.86	PEI n.e.	[MJ]	592.23
		GWP	[kgCO₂.m⁻²]	-9.89	GWP	[kg CO₂]	-3.36
		AP	[kgSO₂.m⁻²]	0.5226	AP	[kg SO₂]	0.17768
		Δ OI3	[Pkt/m²]	126.09			

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Influence of service life:

In the following table (Table 31) it is shown how old the currently used materials are now (2020). The column on the far right shows how often the materials must be changed during the period under consideration. 50 years were chosen as he period under consideration for this work. As in the Scenarios for House A, the values for the service life of the materials shown in the IBO service life catalogue were used. If necessary, these can be read under Table 2 in Chapter 2.8.

Table 31: Substitution durig the period under consideration (source: illustration by the author)

Material		Age in 2020 [years]	Period of use - according to IBO [years]	Substitution during the period under consideration
Supporting structure		30	100	0
Windows	refurbished	0	35	1
Thermal insulation		23	35	2
Plaster		23	35	2
Floor covering: ceramic tiles		27	50	1
Floor covering: linoleum		27	25	2
Floor covering: laminate		25	25	2
Floor covering: textile covering		27	10	5

Table 32 shows the resulting impact of the material exchange during the period under consideration.

Table 32:Impactof Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO_2.m⁻²]	Production GWP [kgCO_2.m⁻²]	** GWP [kg CO_2]	Removal AP [kgSO_2.m⁻²]	Production AP [kg SO_2.m⁻²]	** AP [kg SO_2]
Glazing (windows, door)	12.36	1	7.17	533.96	6,688.37	0.49	40.77	509.97	0.0031000	0.3112	3.88
Frame (windows, door)	6.60	1	0.44	1,741.86	11,499.18	40.37	- 9.89	201.17	0.0000420	0.5226	3.45
Plaster	248.88	2	4.72	29.76	17,162.76	0.34	3.15	1,737.18	0.0000884	0.0083	4.18
Floor covering: ceramic tiles	34.17	1	4.09	649.06	22,318.14	0.30	35.83	1,234.56	0.0018000	0.1288	4.46
Floor covering: linoleum	26.77	2	0.24	419.50	22,472.88	14.36	9.87	1,297.27	0.0000240	0.1040	5.57
Floor covering: laminate	37.13	2	0.15	176.15	13,092.04	11.80	0.88	941.62	0.0000140	0.0355	2.64
Floor covering: textile covering	19.86	5	1.61	82.44	8,346.17	4.05	1.92	592.82	0.0025000	0.0183	2.07
Thermal insulation - EPS (0,08m)	248.88	2	0.77	124.60	62,404.17	6.02	5.25	5,609.76	0.0003690	0.0187	9.49
Sum					**163,983.70**			**12,124.35**			**35.74**

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Influence of heating demand:

The annual heating demand of 170.53 kWh.m^{-2} for this Scenario, which has a heated gross area of 150.42 m² leads to the following amount of produced CO_2 for one year:

	Values per m²	Absolut values
Annual heating demand	170.53 kWh.m^{-2}	25,651.12 kWh
Impact		11,286.49 kg CO_2

Summary of whole Scenario:

The first Scenario for House B devoted to the results shown in Table 33.

Table 33: Sum for Scenario B.1.1 (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO_2]	AP [kg SO_2]	[kg CO_2]
Renovation measure	15,501.86	666.60	6.30	
Use (material exchages)	163,983.70	12,124.35	35.74	564,324.50
SUM	**179,485.56**	**12,790.95**	**42.04**	**564,324.50**

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3.10 Scenario B.1.2

Energy Certificate:

The conducted window exchange of Scenario B.1.2 leaded to a heating requirement of HWB_{SK} = 168.08 $kWh.m^{-2}.a^{-1}$, which again belongs to category E of the Energy Certificate. Figure 38 illustrates that finding.

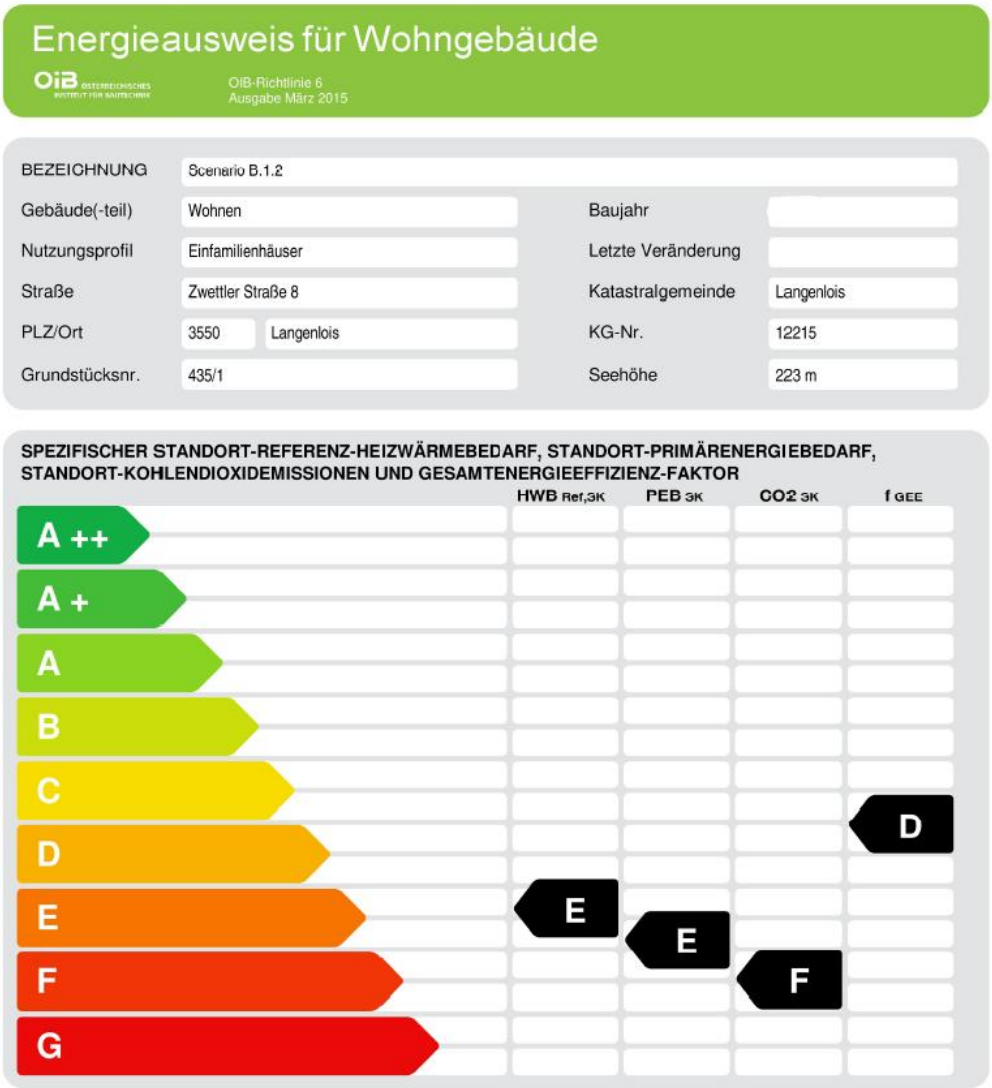

Figure 38: Energy Certificate Scenario B.1.2 (source: illustration taken from ArchiPhysik based on the author's case study buildings)

Impact of removal and impact of production of added materials:

Table 34 shows the removed windows and their originally used materials, whilst in Table 35 the newly added windows are listed.

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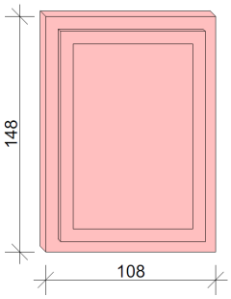
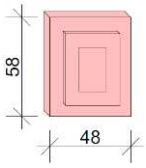
Table 34: Impact of removal (source: illustration by the author)

Window 01 (big)



Double insulation glass			Impact per m²			Absolut Impact		
11.30	m² removed (10x1.13m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	54.01
		GWP	[kgCO_2.m⁻²]	0.33	GWP	[kg CO_2]	3.73
		AP	[kgSO_2.m⁻²]	0.00208	AP	[kg SO_2]	0.02350
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
4.70	m² removed (10x0.47m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	481.75
		GWP	[kg CO_2/m²]	48.21	GWP	[kg CO_2]	226.59
		AP	[kgSO_2.m⁻²]	0.01091	AP	[kg SO_2]	0.05128
		Δ OI3	[Pkt/m²]	12.91			

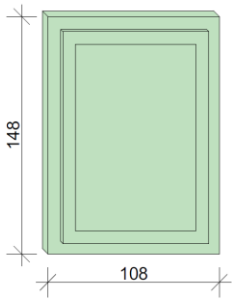
Window 02 (small)



Double insulation glass			Impact per m²			Absolut Impact		
0.22	m² removed (2x0.11m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	1.05
		GWP	[kgCO_2.m⁻²]	0.33	GWP	[kg CO_2]	0.07
		AP	[kgSO_2.m⁻²]	0.00208	AP	[kg SO_2]	0.00046
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
0.34	m² removed (2x0.17m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	34.85
		GWP	[kgCO_2.m⁻²]	48.21	GWP	[kg CO_2]	16.39
		AP	[kgSO_2.m⁻²]	0.01091	AP	[kg SO_2]	0.00371
		Δ OI3	[Pkt/m²]	12.91			

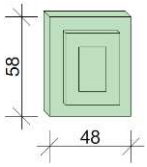
Table 35: Impact of production (source: illustration by the author)

Window 01 (big)



Triple glazing (MGTherm ökostar)			Impact per m²			Absolut Impact		
11.30	m² used (10x1.13m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	6033.75
		GWP	[kgCO_2.m⁻²]	40.77	GWP	[kg CO_2]	460.70
		AP	[kgSO_2.m⁻²]	0.31118	AP	[kg SO_2]	3.51633
		Δ OI3	[Pkt/m²]	66.08			
Wood frame (d = 0.1m) - spruce wood							
4.70	m² used (10x0.47m²)	PEI n.e.	[MJ.m⁻²]	1101.87	PEI n.e.	[MJ]	5178.79
		GWP	[kgCO_2.m⁻²]	-33.026	GWP	[kg CO_2]	-155.22
		AP	[kgSO_2.m⁻²]	0.30521	AP	[kg SO_2]	1.43449
		Δ OI3	[Pkt/m²]	71.92			

Window 03 (small)



Triple glazing (MGTherm ökostar)			Impact per m²			Absolut Impact		
0.22	m² used (2x0.11m²)	PEI n.e.	[MJ.m⁻²]	533.96	PEI n.e.	[MJ]	117.47
		GWP	[kgCO_2.m⁻²]	40.77	GWP	[kg CO_2]	8.97
		AP	[kgSO_2.m⁻²]	0.31118	AP	[kg SO_2]	0.06846
		Δ OI3	[Pkt/m²]	66.08			
Wood frame (d = 0.1m) - spruce wood							
0.34	m² used (2x0.17m²)	PEI n.e.	[MJ.m⁻²]	1101.87	PEI n.e.	[MJ]	374.64
		GWP	[kgCO_2.m⁻²]	-33.026	GWP	[kg CO_2]	-11.23
		AP	[kgSO_2.m⁻²]	0.30521	AP	[kg SO_2]	0.10377
		Δ OI3	[Pkt/m²]	71.92			

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Influence of service life:

Table 36 shows the amount of non-renewable energy resource requirement in mega-joule, the global warming potential in kilogram CO_2 and the amount of acidification potential in kilogram SO_2 of the necessary material exchange during the period under consideration of Scenario B.1.2. The values are shown in per m² as well as absolute values for the corresponding Scenario.

Table 36: Impact of Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO₂.m⁻²]	Production GWP [kgCO₂.m⁻²]	** GWP [kg CO₂]	Removal AP [kgSO₂.m⁻²]	Production AP [kg SO₂.m⁻²]	** AP [kg SO₂]
Glazing (windows, door)	12.36	1	7.17	533.96	6,688.37	0.49	40.77	509.97	0.0031000	0.3112	3.88
Frame (windows, door)	6.60	1	0.44	1,101.87	7,275.25	40.37	- 33.03	48.44	0.0000420	0.3052	2.01
Plaster	248.88	2	4.72	29.76	17,162.76	0.34	3.15	1,737.18	0.0000884	0.0083	4.18
Floor covering: ceramic tiles	34.17	1	4.09	649.06	22,318.14	0.30	35.83	1,234.56	0.0018000	0.1288	4.46
Floor covering: linoleum	26.77	2	0.24	419.50	22,472.88	14.36	9.87	1,297.27	0.0000240	0.1040	5.57
Floor covering: laminate	37.13	2	0.15	176.15	13,092.04	11.80	0.88	941.62	0.0000140	0.0355	2.64
Floor covering: textile covering	19.86	5	1.61	82.44	8,346.17	4.05	1.92	592.82	0.0025000	0.0183	2.07
Thermal insulation - EPS (0,08m)	242.45	2	0.77	124.60	60,791.91	6.02	5.25	5,464.82	0.0003690	0.0187	9.25
Sum					**158,147.51**			**11,826.70**			**34.06**

Influence of heating demand:

Scenario B.1.2 has an annual heating demand of 168,08 kWh/m². The heated gross area again is 150.42 m². Therefore, the impact for heating the House after the renovation measure of Scenario B.1.2 leads to the following amount of CO_2 each year:

	Values per m²	Absolut values
Annual heating demand	168.08 kWh.m⁻²	25,282.59 kWh
Impact		11,124.34 kg CO_2

Summary of whole Scenario:

All measures taken for this Scenario lead to the results shown in Table 37.

Table 37: Sum for Scenario B.1.2 (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO_2]	AP [kg SO_2]	[kg CO_2]
Renovation measure	12,276.31	550.00	5.20	
Use (material exchages)	158,147.51	11,826.70	34.06	556,217.00
SUM	**170,423.82**	**12,376.70**	**39.26**	**556,217.00**

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3.11 Scenario B.2.1

Energy Certificate:

Renovating the exterior walls as well as the ceiling to the unheated attic lead to a heating demand of HWB_{SK} = 109.04 $kWh.m^{-2}.a^{-1}$. This is classified in category D of the Energy Certificate, which can be seen in Figure 39.

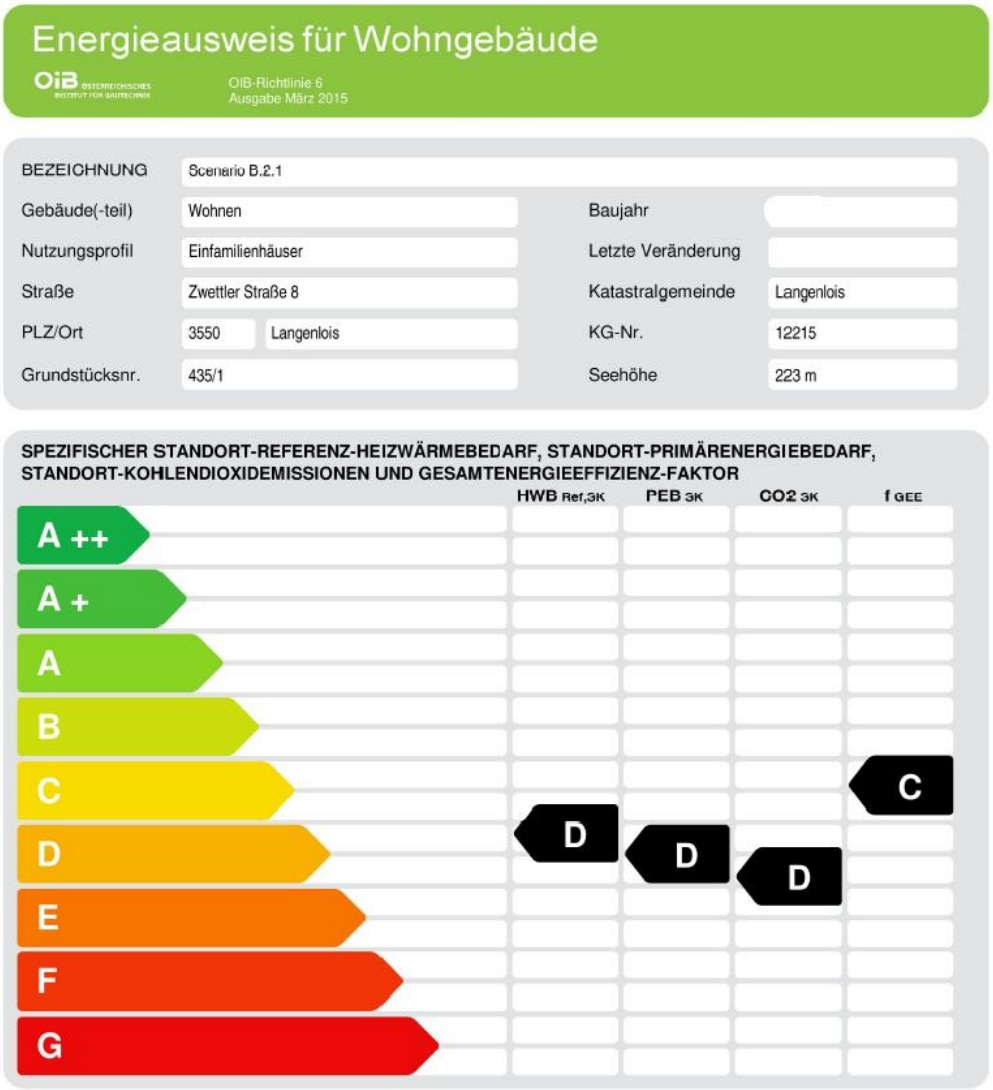

Figure 39: Energy Certificate Scenario B.2.1 (source: illustration taken from ArchiPhysik based on the author's case study buildings)

Impact of removal and impact of production of added materials:

Table 38 lists the impact of the removal of the originally used materials. In Table 39 all the building components which has to be added are shown there. Removed or added material layers are highlighted.

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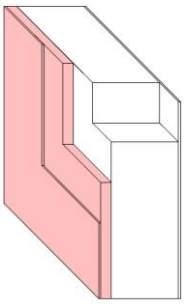
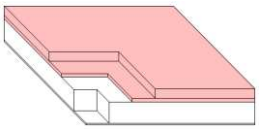
Table 38: Impact of removal (source: illustration by the author)

Exterior walls



0.015 m Exterior plaster		Impact per m²			Absolut Impact		
245.86	m² removed	PEI n.e.	[MJ.m⁻²]	4.72	PEI n.e.	[MJ]	1160.46
		GWP	[kgCO_2.m⁻²]	0.34	GWP	[kg CO_2]	83.59
		AP	[kgSO_2.m⁻²]	0.0000884	AP	[kg SO_2]	0.02173
		Δ OI3	[Pkt/m²]	0.23			
0.08 m EPS							
245.86	m² removed	PEI n.e.	[MJ.m⁻²]	0.77	PEI n.e.	[MJ]	189.31
		GWP	[kgCO_2.m⁻²]	6.02	GWP	[kg CO_2]	1480.08
		AP	[kgSO_2.m⁻²]	0.000369	AP	[kg SO_2]	0.0907
		Δ OI3	[Pkt/m²]	1.08			

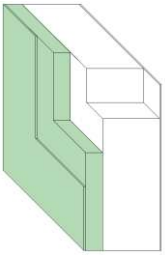
Ceiling to unheated attic



0.03 m Footfall sound insulation		Impact per m²			Absolut Impact		
150.42	m² removed	PEI n.e.	[MJ.m⁻²]	0.53	PEI n.e.	[MJ]	79.72
		GWP	[kgCO_2.m⁻²]	3.55	GWP	[kg CO_2]	533.99
		AP	[kgSO_2.m⁻²]	0.000282	AP	[kg SO_2]	0.0424
		Δ OI3	[Pkt/m²]	0.65			
0.08 Screed (Cementscreed)							
150.42	m² removed	PEI n.e.	[MJ.m⁻²]	42.05	PEI n.e.	[MJ]	6325.16
		GWP	[kgCO_2.m⁻²]	2.88	GWP	[kg CO_2]	433.21
		AP	[kgSO_2.m⁻²]	0.018303	AP	[kg SO_2]	2.7531
		Δ OI3	[Pkt/m²]	4.32			

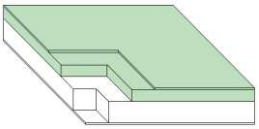
Table 39: Impact of production (source: illustration by the author)

Exterior walls



0.015 m Heat insulation plaster		Impact per m²			Absolut Impact		
248.88	m² used	PEI n.e.	[MJ.m⁻²]	29.76	PEI n.e.	[MJ]	7406.67
		GWP	[kgCO_2.m⁻²]	3.15	GWP	[kg CO_2]	783.97
		AP	[kgSO_2.m⁻²]	0.0083	AP	[kg SO_2]	2.0657
		Δ OI3	[Pkt/m²]	2.62			
0.15 m EPS							
248.88	m² used	PEI n.e.	[MJ.m⁻²]	234.38	PEI n.e.	[MJ]	58332.49
		GWP	[kgCO_2.m⁻²]	9.88	GWP	[kg CO_2]	2458.93
		AP	[kgSO_2.m⁻²]	0.0353	AP	[kg SO_2]	8.7855
		Δ OI3	[Pkt/m²]	14.17			

Ceiling to unheated attic



0.1 m XPS-R		Impact per m²			Absolut Impact		
150.42	m² used	PEI n.e.	[MJ.m⁻²]	377.91	PEI n.e.	[MJ]	56845.22
		GWP	[kgCO_2.m⁻²]	15.97	GWP	[kg CO_2]	2402.21
		AP	[kgSO_2.m⁻²]	0.0589	AP	[kg SO_2]	8.8597
		Δ OI3	[Pkt/m²]	23.11			
0.015 m Oriented strand board							
150.42	m² used	PEI n.e.	[MJ.m⁻²]	83.42	PEI n.e.	[MJ]	12548.036
		GWP	[kgCO_2.m⁻²]	-11.22	GWP	[kg CO_2]	-1687.71
		AP	[kgSO_2.m⁻²]	0.0204	AP	[kg SO_2]	3.0686
		Δ OI3	[Pkt/m²]	3.63			

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Influence of service life:

Table 40 show the age of the materials and the times how often they must be replaced during the considered period of 50 years during operation.

Table 40: Substitution during the period under consideration (source: illustration by the author)

Material		Age in 2020 [years]	Period of use - according to IBO [years]	Substitution during the period under consideration
Supporting structure		30	100	0
Windows		29	35	2
Thermal insulation	refurbished	0	35	1
Plaster	refurbished	0	35	1
Floor covering: ceramic tiles		27	50	1
Floor covering: linoleum		27	25	2
Floor covering: laminate		25	25	2
Floor covering: textile covering		27	10	5

Table 41 represents the impact of changed materials during the use-phase of 50 years.

Table 41: Impact of Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO_2.m⁻²]	Production GWP [kgCO_2.m⁻²]	** GWP [kg CO_2]	Removal AP [kgSO_2.m⁻²]	Production AP [kg SO_2.m⁻²]	** AP [kg SO_2]
Glazing (windows, door)	12.36	2	4.78	410.40	10,263.25	0.33	32.67	815.76	0.0020800	0.26763	6.67
Frame - plastic (windows, door)	6.60	2	102.50	3,403.67	46,281.44	48.21	151.06	2,630.36	0.0109100	0.55946	7.53
Plaster	248.88	1	4.72	29.76	8,581.38	0.34	3.15	868.59	0.0000884	0.00830	2.09
Floor covering: ceramic tiles	34.17	1	4.09	649.06	22,318.14	0.30	35.83	1,234.56	0.0018000	0.12880	4.46
Floor covering: linoleum	26.77	2	0.24	419.50	22,472.88	14.36	9.87	1,297.27	0.0000240	0.10400	5.57
Floor covering: laminate	37.13	2	0.15	176.15	13,092.04	11.80	0.88	941.62	0.0000140	0.03550	2.64
Floor covering: textile covering	19.86	5	1.61	82.44	8,346.17	4.05	1.92	592.82	0.0025000	0.01830	2.07
Thermal insulation - EPS (0,15m)	248.88	1	1.44	234.38	58,690.88	11.28	9.88	5,266.30	0.0006920	0.03530	8.96
Thermal insulation - XPS (0,1m)	150.42	1	1.78	377.91	57,112.97	11.82	15.97	4,180.17	0.0009390	0.05890	9.00
Sum					**247,159.15**			**17,827.46**			**48.98**

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Influence of heating demand:

The conducted Energy Certificate for this Scenario resulted in a heating demand of 109.04 kWh per square meter and year. This heating requirements leads to the following amount of CO_2 every year:

	Values per m²	Absolut values
Annual heating demand	109.04 kWh.m^{-2}	16,401.80 kWh
Impact		7,216.79 kg CO_2

Summary of whole Scenario:

Scenario B.2.1 leads to the following environmental impacts in terms of the environmental indicators presented, based on a 50-year use (Table 42).

Table 42: Sum for Scenario B.2.1 (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO_2]	AP [kg SO_2]	[kg CO_2]
Renovation measure	142,887.08	6,488.17	25.69	
Use (material exchages)	247,159.15	17,827.46	48.98	360,839.50
SUM	**390,046.23**	**24,315.63**	**74.67**	**360,839.50**

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3.12 Scenario B.2.2

Energy Certificate:

In Figure 40 the Energy Certificate of Scenario B.2.2 is represented. It shows that the renovation measures of Scenario B.2.2 have led the building being placed in category D in terms of heating requirement. A heating requirement of HWB_{SK} = 120.64 $kWh.m^{-2}.a^{-1}$ is needed here to heat up the space.

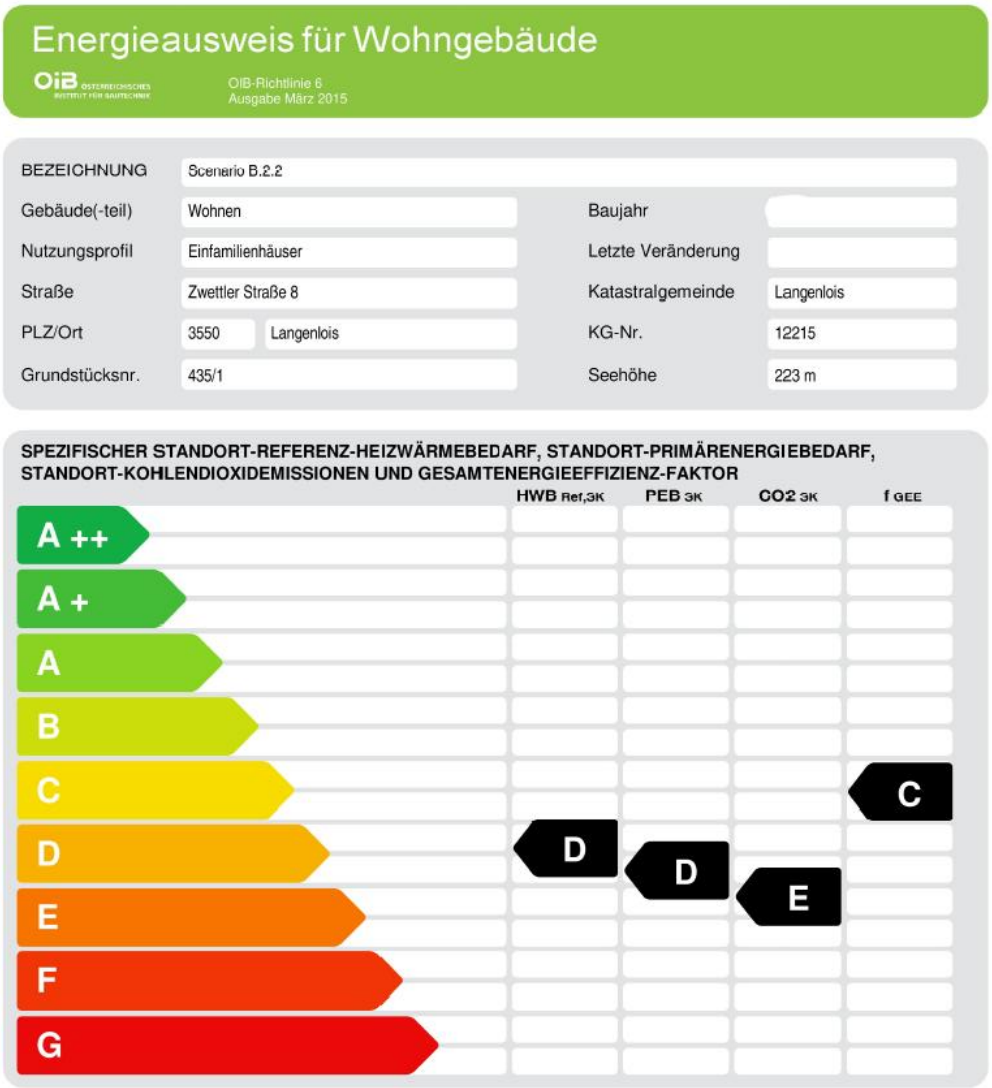

Figure 40: Energy Certificate Scenario B.2.2 (source: illustration taken from ArchiPhysik based on the author's case study buildings)

Impact of removal and impact of production of added materials:

Table 43 shows which materials are removed and the corresponding impact. In Table 44 the impact of producing the new materials is shown.

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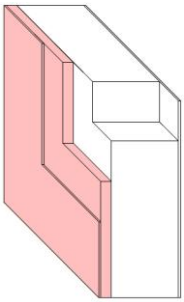
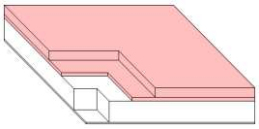
Table 43: Impact of removal (source: illustration by the author)

Exterior walls



0.015 m Exterior plaster		Impact per m²			Absolut Impact		
245.86 m² removed	PEI n.e.	[MJ.m⁻²]	4.72	PEI n.e.	[MJ]	1160.46
	GWP	[kgCO$_2$.m⁻²]	0.34	GWP	[kg CO$_2$]	83.59
	AP	[kgSO$_2$.m⁻²]	0.0000884	AP	[kg SO$_2$]	0.02173
	Δ OI3	[Pkt/m²]	0.23			
0.08 m EPS						
245.86 m² removed	PEI n.e.	[MJ.m⁻²]	0.77	PEI n.e.	[MJ]	189.31
	GWP	[kgCO$_2$.m⁻²]	6.02	GWP	[kg CO$_2$]	1480.08
	AP	[kgSO$_2$.m⁻²]	0.000369	AP	[kg SO$_2$]	0.0907
	Δ OI3	[Pkt/m²]	1.08			

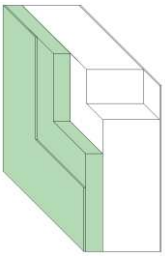
Ceiling to unheated attic



0.03 m Footfall sound insulation		Impact per m²			Absolut Impact		
150.42 m² removed	PEI n.e.	[MJ.m⁻²]	0.53	PEI n.e.	[MJ]	79.72
	GWP	[kgCO$_2$.m⁻²]	3.55	GWP	[kg CO$_2$]	533.99
	AP	[kgSO$_2$.m⁻²]	0.000282	AP	[kg SO$_2$]	0.0424
	Δ OI3	[Pkt/m²]	0.65			
0.08 Screed (Cementscreed)						
150.42 m² removed	PEI n.e.	[MJ.m⁻²]	42.05	PEI n.e.	[MJ]	6325.16
	GWP	[kgCO$_2$.m⁻²]	2.88	GWP	[kg CO$_2$]	433.21
	AP	[kgSO$_2$.m⁻²]	0.018303	AP	[kg SO$_2$]	2.7531
	Δ OI3	[Pkt/m²]	4.32			

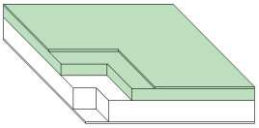
Table 44: Impact of production (source: illustration by the author)

Exterior walls



0.015 m Heat insulation plaster		Impact per m²			Absolut Impact		
248.88 m² used	PEI n.e.	[MJ.m⁻²]	29.76	PEI n.e.	[MJ]	7406.67
	GWP	[kgCO$_2$.m⁻²]	3.15	GWP	[kg CO$_2$]	783.97
	AP	[kgSO$_2$.m⁻²]	0.0083	AP	[kg SO$_2$]	2.0657
	Δ OI3	[Pkt/m²]	2.62			
0.15 m Wood fber board						
248.88 m² used	PEI n.e.	[MJ.m⁻²]	349.87	PEI n.e.	[MJ]	87075.65
	GWP	[kgCO$_2$.m⁻²]	-18.09	GWP	[kg CO$_2$]	-4502.24
	AP	[kgSO$_2$.m⁻²]	0.09	AP	[kg SO$_2$]	22.3992
	Δ OI3	[Pkt/m²]	20.65			

Ceiling to unheated attic



0.1 m Wood fiber board		Impact per m²			Absolut Impact		
150.42 m² used	PEI n.e.	[MJ.m⁻²]	233.25	PEI n.e.	[MJ]	35085.47
	GWP	[kgCO$_2$.m⁻²]	-12.06	GWP	[kg CO$_2$]	-1814.07
	AP	[kgSO$_2$.m⁻²]	0.06	AP	[kg SO$_2$]	9.0252
	Δ OI3	[Pkt/m²]	13.77			
0.015 m Oriented strand board						
150.42 m² used	PEI n.e.	[MJ.m⁻²]	83.42	PEI n.e.	[MJ]	12548.036
	GWP	[kgCO$_2$.m⁻²]	-11.22	GWP	[kg CO$_2$]	-1687.71
	AP	[kgSO$_2$.m⁻²]	0.0204	AP	[kg SO$_2$]	3.0686
	Δ OI3	[Pkt/m²]	3.63			

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Influence of service life:

In Table 45 the impact for the necessary changings of materials during the considered period of 50 years usage are shown. Both the removal of the old materials and the production of the new materials were taken into account and were calculated.

Table 45: Impact of Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO₂.m⁻²]	Production GWP [kgCO₂.m⁻²]	** GWP [kg CO₂]	Removal AP [kgSO₂.m⁻²]	Production AP [kg SO₂.m⁻²]	** AP [kg SO₂]
Glazing (windows, door)	12.36	2	4.78	410.40	10,263.25	0.33	32.67	815.76	0.0020800	0.26763	6.67
Frame - plastic (windows, door)	6.60	2	102.50	3,403.67	46,281.44	48.21	151.06	2,630.36	0.0109100	0.55946	7.53
Plaster	248.88	1	4.72	29.76	8,581.38	0.34	3.15	868.59	0.0000884	0.00830	2.09
Floor covering: ceramic tiles	34.17	1	4.09	649.06	22,318.14	0.30	35.83	1,234.56	0.0018000	0.12880	4.46
Floor covering: linoleum	26.77	2	0.24	419.50	22,472.88	14.36	9.87	1,297.27	0.0000240	0.10400	5.57
Floor covering: laminate	37.13	2	0.15	176.15	13,092.04	11.80	0.88	941.62	0.0000140	0.03550	2.64
Floor covering: textile covering	19.86	5	1.61	82.44	8,346.17	4.05	1.92	592.82	0.0025000	0.01830	2.07
Thermal insulation - wood fiber board - wall (0,15m)	248.88	1	0.55	349.87	87,212.53	50.21	- 18.09	7,994.03	0.0000520	0.09000	22.41
Thermal insulation - wood fiber board - ceiling (0,1m)	129.19	1	0.37	233.25	30,181.37	33.47	- 12.06	2,765.96	0.0000340	0.06000	7.76
Sum					**248,749.19**			**19,140.97**			**61.19**

Influence of heating demand:

Having a heating demand of 120.64 kWh.m^{-2}.a^{-1} and a heated gross area of 150.42m² means the following amount of CO_2 every year for heating:

	Values per m²	Absolut values
Annual heating demand	120.64 kWh.m^{-2}	18,146.67 kWh
Impact		7,984.53 kg CO_2

Summary of whole Scenario:

Table 46 sums up the environmental impact for Scenario B.2.2.

Table 46: Sum for Scenario B.2.2 (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO_2]	AP [kg SO_2]	[kg CO_2]
Renovation measure	149,870.47	- 4,689.17	39.47	
Use (material exchages)	248,749.19	19,140.97	61.19	399,226.50
SUM	**398,619.66**	**14,451.80**	**100.66**	**399,226.50**

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3.13 Scenario B.3

Energy Certificate:

Figure 41 shows that it was possible to bring House B up to category B of the Energy Certificate because of the conducted renovation measures. A HWB_{SK} of 47.33 $kWh.m^{-2}.a^{-1}$ could be achieved.

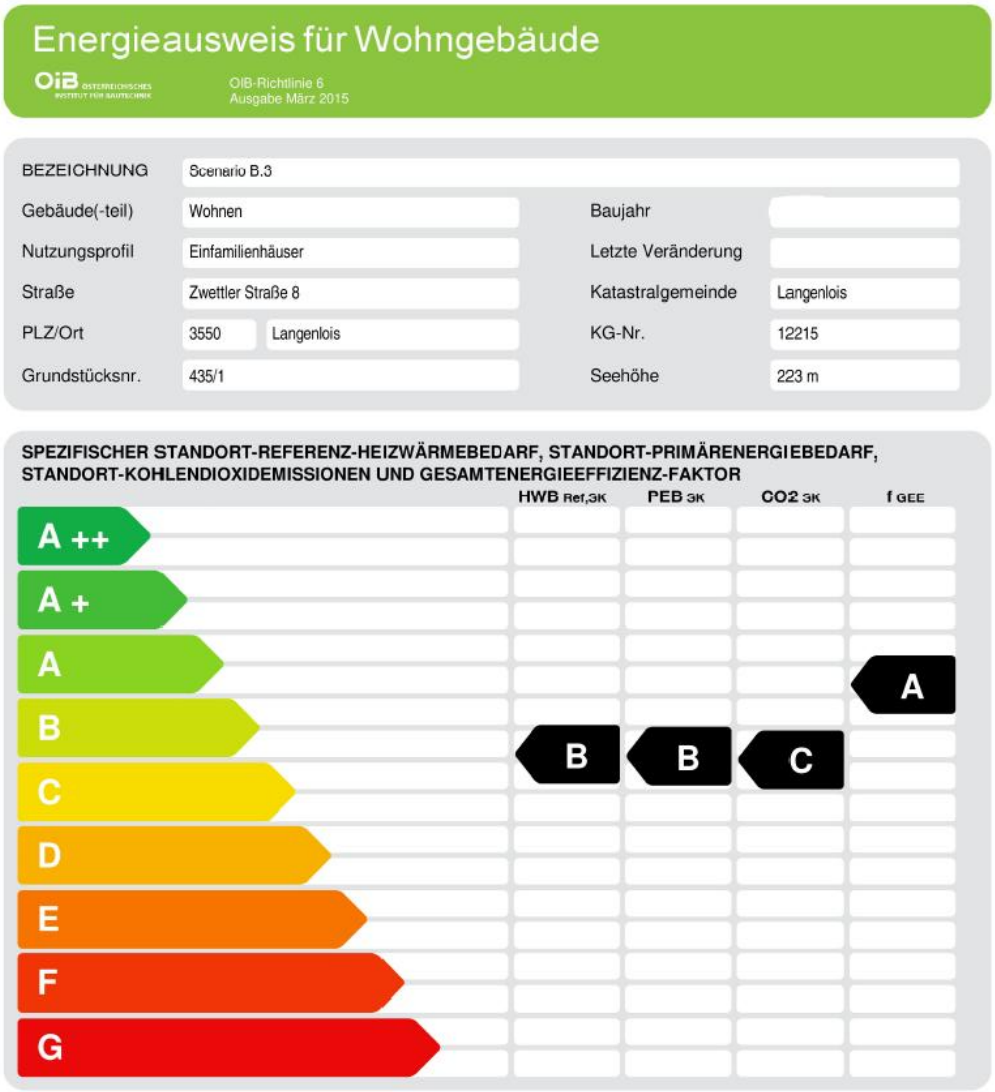

Figure 41: Energy Certificate Scenario B.3 (source: illustration taken from ArchiPhysik based on the author's case study buildings)

Impact of removal and impact of production of added materials:

In the following two tables (Table 47, Table 48) the impact of removing the old materials of the building components which are renovated are shown. Table 49, Table 50 and Table 51 list the impact of producing the new materials.

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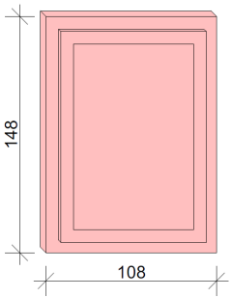
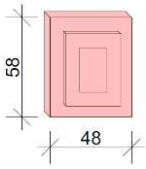
Table 47: Impact of removal (Part 1) (source: illustration by the author)

Window 01 (big)



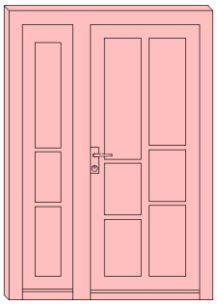
Double insulation glass		Impact per m²			Absolut Impact		
11.30	m² removed (10x1.13m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	54.01
		GWP	[kgCO₂.m⁻²]	0.33	GWP	[kg CO₂]	3.73
		AP	[kgSO₂.m⁻²]	0.00208	AP	[kg SO₂]	0.02350
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
4.70	m² removed (10x0.47m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	481.75
		GWP	[kgCO₂.m⁻²]	48.21	GWP	[kg CO₂]	226.59
		AP	[kgSO₂.m⁻²]	0.01091	AP	[kg SO₂]	0.05128
		Δ OI3	[Pkt/m²]	12.91			

Window 02 (small)



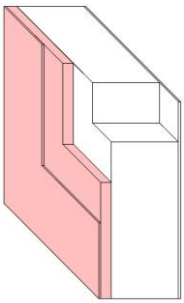
Double insulation glass		Impact per m²			Absolut Impact		
0.22	m² removed (2x0.11m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	1.05
		GWP	[kgCO₂.m⁻²]	0.33	GWP	[kg CO₂]	0.07
		AP	[kgSO₂.m⁻²]	0.00208	AP	[kg SO₂]	0.00046
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
0.34	m² removed (2x0.17m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	34.85
		GWP	[kgCO₂.m⁻²]	48.21	GWP	[kg CO₂]	16.39
		AP	[kgSO₂.m⁻²]	0.01091	AP	[kg SO₂]	0.00371
		Δ OI3	[Pkt/m²]	12.91			

Entrance door



Double insulation glass		Impact per m²			Absolut Impact		
0.84	m² removed (1x0.84m²)	PEI n.e.	[MJ.m⁻²]	4.78	PEI n.e.	[MJ]	4.02
		GWP	[kgCO₂.m⁻²]	0.33	GWP	[kg CO₂]	0.28
		AP	[kgSO₂.m⁻²]	0.00208	AP	[kg SO₂]	0.00175
		Δ OI3	[Pkt/m²]	0.49			
Plastic frame (d = 0.1m)							
1.56	m² removed (1x1.56m²)	PEI n.e.	[MJ.m⁻²]	102.5	PEI n.e.	[MJ]	159.90
		GWP	[kgCO₂.m⁻²]	48.21	GWP	[kg CO₂]	75.21
		AP	[kgSO₂.m⁻²]	0.01091	AP	[kg SO₂]	0.01702
		Δ OI3	[Pkt/m²]	12.91			

Exterior walls



0.015 m Exterior plaster		Impact per m²			Absolut Impact		
245.86	m² removed	PEI n.e.	[MJ.m⁻²]	4.72	PEI n.e.	[MJ]	1160.46
		GWP	[kgCO₂.m⁻²]	0.34	GWP	[kg CO₂]	83.59
		AP	[kgSO₂.m⁻²]	0.0000884	AP	[kg SO₂]	0.02173
		Δ OI3	[Pkt/m²]	0.23			
0.08 m EPS							
245.86	m² removed	PEI n.e.	[MJ.m⁻²]	0.77	PEI n.e.	[MJ]	189.31
		GWP	[kgCO₂.m⁻²]	6.02	GWP	[kg CO₂]	1480.08
		AP	[kgSO₂.m⁻²]	0.000369	AP	[kg SO₂]	0.0907
		Δ OI3	[Pkt/m²]	1.08			

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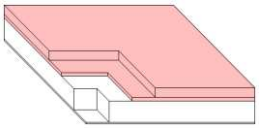
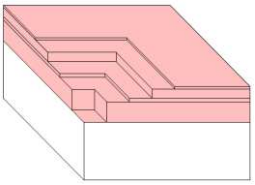
Table 48: Impact of removal (Part 2) (source: illustration by the author)

Ceiling to unheated attic



0.03 m Footfall sound insulation		Impact per m²		Absolut Impact	
150.42 m² removed	PEI n.e. [MJ.m⁻²]	0.53	PEI n.e. [MJ]	79.72
	GWP [$kgCO_2.m^{-2}$]	3.55	GWP [$kg\ CO_2$]	533.99
	AP [$kgSO_2.m^{-2}$]	0.000282	AP [$kg\ SO_2$]	0.0424
	Δ OI3 [Pkt/m²]	0.65		
0.08 Screed (Cementscreed)				
150.42 m² removed	PEI n.e. [MJ.m⁻²]	42.05	PEI n.e. [MJ]	6325.16
	GWP [$kgCO_2.m^{-2}$]	2.88	GWP [$kg\ CO_2$]	433.21
	AP [$kgSO_2.m^{-2}$]	0.018303	AP [$kg\ SO_2$]	2.7531
	Δ OI3 [Pkt/m²]	4.32		

Ceiling to ground



0.001 m Sealing		Impact per m²		Absolut Impact	
117.93 m² removed	PEI n.e. [MJ.m⁻²]	0.67	PEI n.e. [MJ]	79.01
	GWP [$kgCO_2.m^{-2}$]	4.15	GWP [$kg\ CO_2$]	489.41
	AP [$kgSO_2.m^{-2}$]	0.0003744	AP [$kg\ SO_2$]	0.0442
	Δ OI3 [Pkt/m²]	0.65		
0.18 m Concrete (C25/30)				
117.93 m² removed	PEI n.e. [MJ.m⁻²]	14.17	PEI n.e. [MJ]	1671.07
	GWP [$kgCO_2.m^{-2}$]	1.08	GWP [$kg\ CO_2$]	127.36
	AP [$kgSO_2.m^{-2}$]	0.002034	AP [$kg\ SO_2$]	0.2399
	Δ OI3 [Pkt/m²]	0.92		
0.03 m Footfall sound insulation				
117.93 m² removed	PEI n.e. [MJ.m⁻²]	0.53	PEI n.e. [MJ]	62.50
	GWP [$kgCO_2.m^{-2}$]	3.55	GWP [$kg\ CO_2$]	418.65
	AP [$kgSO_2.m^{-2}$]	0.000282	AP [$kg\ SO_2$]	0.0333
	Δ OI3 [Pkt/m²]	0.65		
0.08 m Screed (Cementscreed)				
117.93 m² removed	PEI n.e. [MJ.m⁻²]	42.05	PEI n.e. [MJ]	4958.96
	GWP [$kgCO_2.m^{-2}$]	2.88	GWP [$kg\ CO_2$]	339.64
	AP [$kgSO_2.m^{-2}$]	0.018303	AP [$kg\ SO_2$]	2.1585
	Δ OI3 [Pkt/m²]	4.32		
0.02 m Tiles				
34.17 m² removed	PEI n.e. [MJ.m⁻²]	4.09	PEI n.e. [MJ]	139.76
	GWP [$kgCO_2.m^{-2}$]	0.30	GWP [$kg\ CO_2$]	10.25
	AP [$kgSO_2.m^{-2}$]	0.0018	AP [$kg\ SO_2$]	0.0615
	Δ OI3 [Pkt/m²]	0.43		
0.01 m Linoleum				
26.77 m² removed	PEI n.e. [MJ.m⁻²]	0.24	PEI n.e. [MJ]	6.42
	GWP [$kgCO_2.m^{-2}$]	14.36	GWP [$kg\ CO_2$]	384.42
	AP [$kgSO_2.m^{-2}$]	0.000024	AP [$kg\ SO_2$]	0.0006
	Δ OI3 [Pkt/m²]	2.40		
0.01 m Carpet				
37.13 m² removed	PEI n.e. [MJ.m⁻²]	1.61	PEI n.e. [MJ]	59.78
	GWP [$kgCO_2.m^{-2}$]	4.05	GWP [$kg\ CO_2$]	150.38
	AP [$kgSO_2.m^{-2}$]	0.0025	AP [$kg\ SO_2$]	0.0928
	Δ OI3 [Pkt/m²]	1.06		
0.01 m Laminate				
19.86 m² removed	PEI n.e. [MJ.m⁻²]	0.15	PEI n.e. [MJ]	2.98
	GWP [$kgCO_2.m^{-2}$]	11.80	GWP [$kg\ CO_2$]	234.35
	AP [$kgSO_2.m^{-2}$]	0.000014	AP [$kg\ SO_2$]	0.0003
	Δ OI3 [Pkt/m²]	1.97		

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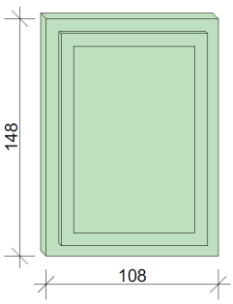
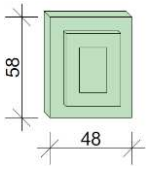
Table 49: Impact of production (Part 1) (source: illustration by the author)

Window 01 (big)



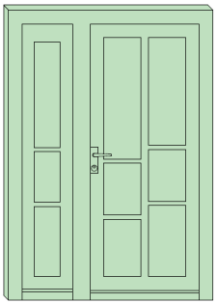
Triple glazing			Impact per m²			Absolut Impact		
11.30	m² used (10x1.13m²)	PEI n.e.	[MJ.m⁻²]	533.96		PEI n.e.	[MJ]	6033.75
		GWP	[kgCO₂.m⁻²]	40.77		GWP	[kg CO₂]	460.70
		AP	[kgSO₂.m⁻²]	0.31118		AP	[kg SO₂]	3.51633
		Δ OI3	[Pkt/m²]	66.08				
Wood frame (d = 0.1m) - spruce wood								
4.70	m² used (10x0.47m²)	PEI n.e.	[MJ.m⁻²]	1101.87		PEI n.e.	[MJ]	5178.79
		GWP	[kgCO₂.m⁻²]	-33.026		GWP	[kg CO₂]	-155.22
		AP	[kgSO₂.m⁻²]	0.30521		AP	[kg SO₂]	1.43449
		Δ OI3	[Pkt/m²]	71.92				

Window 03 (small)



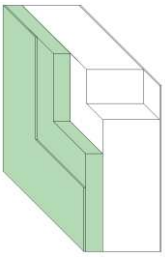
Triple glazing			Impact per m²			Absolut Impact		
0.22	m² used (2x0.11m²)	PEI n.e.	[MJ.m⁻²]	533.96		PEI n.e.	[MJ]	117.47
		GWP	[kgCO₂.m⁻²]	40.77		GWP	[kg CO₂]	8.97
		AP	[kgSO₂.m⁻²]	0.31118		AP	[kg SO₂]	0.06846
		Δ OI3	[Pkt/m²]	66.08				
Wood frame (d = 0.1m) - spruce wood								
0.34	m² used (2x0.17m²)	PEI n.e.	[MJ.m⁻²]	1101.87		PEI n.e.	[MJ]	374.64
		GWP	[kgCO₂.m⁻²]	-33.026		GWP	[kg CO₂]	-11.23
		AP	[kgSO₂.m⁻²]	0.30521		AP	[kg SO₂]	0.10377
		Δ OI3	[Pkt/m²]	71.92				

Entrance door



Triple glazing			Impact per m²			Absolut Impact		
0.84	m² used (1x0.84m²)	PEI n.e.	[MJ.m⁻²]	533.96		PEI n.e.	[MJ]	448.53
		GWP	[kgCO₂.m⁻²]	40.77		GWP	[kg CO₂]	34.25
		AP	[kgSO₂.m⁻²]	0.31118		AP	[kg SO₂]	0.26139
		Δ OI3	[Pkt/m²]	66.08				
Wood frame (d = 0.1m) - spruce wood								
1.56	m² used (1x1.56m²)	PEI n.e.	[MJ.m⁻²]	1101.87		PEI n.e.	[MJ]	1718.92
		GWP	[kgCO₂.m⁻²]	-33.026		GWP	[kg CO₂]	-51.52
		AP	[kgSO₂.m⁻²]	0.30521		AP	[kg SO₂]	0.47613
		Δ OI3	[Pkt/m²]	71.92				

Exterior walls



0.015 m Heat insulation plaster			Impact per m²			Absolut Impact		
248.88	m² used	PEI n.e.	[MJ.m⁻²]	29.76		PEI n.e.	[MJ]	7406.67
		GWP	[kgCO₂.m⁻²]	3.15		GWP	[kg CO₂]	783.97
		AP	[kgSO₂.m⁻²]	0.0083		AP	[kg SO₂]	2.0657
		Δ OI3	[Pkt/m²]	2.62				
0.2 m EPS								
248.88	m² used	PEI n.e.	[MJ.m⁻²]	312.50		PEI n.e.	[MJ]	77775.00
		GWP	[kgCO₂.m⁻²]	13.17		GWP	[kg CO₂]	3277.75
		AP	[kgSO₂.m⁻²]	0.0470		AP	[kg SO₂]	11.6974
		Δ OI3	[Pkt/m²]	18.88				

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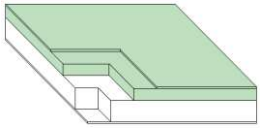
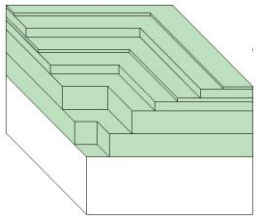
Table 50: Impact of production (Part 2) (source: illustration by the author)

Ceiling to unheated attic



0.2 m XPS-R		Impact per m²			Absolut Impact		
150.42	m² used	PEI n.e.	[MJ.m⁻²]	755.82	PEI n.e.	[MJ]	113690.44
		GWP	[kgCO$_2$.m⁻²]	31.95	GWP	[kg CO$_2$]	4805.92
		AP	[kgSO$_2$.m⁻²]	0.1178	AP	[kg SO$_2$]	17.7195
		Δ OI3	[Pkt/m²]	46.23			
0.015 m Oriented strand board							
150.42	m² used	PEI n.e.	[MJ.m⁻²]	83.42	PEI n.e.	[MJ]	12548.036
		GWP	[kgCO$_2$.m⁻²]	-11.22	GWP	[kg CO$_2$]	-1687.71
		AP	[kgSO$_2$.m⁻²]	0.0204	AP	[kg SO$_2$]	3.0686
		Δ OI3	[Pkt/m²]	3.63			

Ceilings to ground



0.2 m XPS-G 50		Impact per m²			Absolut Impact		
117.93	m² used	PEI n.e.	[MJ.m⁻²]	711.09	PEI n.e.	[MJ]	83858.84
		GWP	[kgCO$_2$.m⁻²]	31.95	GWP	[kg CO$_2$]	3767.86
		AP	[kgSO$_2$.m⁻²]	0.1180	AP	[kg SO$_2$]	13.91574
		Δ OI3	[Pkt/m²]	44.76			
0.2 m Concrete							
117.93	m² used	PEI n.e.	[MJ.m⁻²]	504.00	PEI n.e.	[MJ]	59436.72
		GWP	[kgCO$_2$.m⁻²]	66.72	GWP	[kg CO$_2$]	7868.29
		AP	[kgSO$_2$.m⁻²]	0.1440	AP	[kg SO$_2$]	16.98192
		Δ OI3	[Pkt/m²]	47.12			
0.001 m Sealing							
117.93	m² used	PEI n.e.	[MJ.m⁻²]	8.17	PEI n.e.	[MJ]	963.49
		GWP	[kgCO$_2$.m⁻²]	0.23	GWP	[kg CO$_2$]	27.12
		AP	[kgSO$_2$.m⁻²]	0.0013	AP	[kg SO$_2$]	0.15331
		Δ OI3	[Pkt/m²]	0.48			
0.08 m EPS granulate levelling compound							
117.93	m² used	PEI n.e.	[MJ.m⁻²]	113.47	PEI n.e.	[MJ]	13381.52
		GWP	[kgCO$_2$.m⁻²]	8.65	GWP	[kg CO$_2$]	1020.09
		AP	[kgSO$_2$.m⁻²]	0.0204	AP	[kg SO$_2$]	2.40577
		Δ OI3	[Pkt/m²]	7.94			
0.03 m Footfall sound insulation							
117.93	m² used	PEI n.e.	[MJ.m⁻²]	32.63	PEI n.e.	[MJ]	3848.06
		GWP	[kgCO$_2$.m⁻²]	1.37	GWP	[kg CO$_2$]	161.56
		AP	[kgSO$_2$.m⁻²]	0.0049	AP	[kg SO$_2$]	0.57786
		Δ OI3	[Pkt/m²]	1.97			
0.001 m PE-foil							
117.93	m² used	PEI n.e.	[MJ.m⁻²]	90.07	PEI n.e.	[MJ]	10621.96
		GWP	[kgCO$_2$.m⁻²]	4.96	GWP	[kg CO$_2$]	584.93
		AP	[kgSO$_2$.m⁻²]	0.0235	AP	[kg SO$_2$]	2.77136
		Δ OI3	[Pkt/m²]	6.96			
0.08 m Screed							
117.93	m² used	PEI n.e.	[MJ.m⁻²]	140.80	PEI n.e.	[MJ]	16604.54
		GWP	[kgCO$_2$.m⁻²]	15.36	GWP	[kg CO$_2$]	1811.40
		AP	[kgSO$_2$.m⁻²]	0.0384	AP	[kg SO$_2$]	4.52851
		Δ OI3	[Pkt/m²]	12.37			

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Table 51: Impact of production (Part 3) (source: illustration by the author)

0.02 m Tiles							
34.17	m² used	PEI n.e.	[MJ.m⁻²]	649.06	PEI n.e.	[MJ]	22178.38
		GWP	[kgCO_2.m⁻²]	35.83	GWP	[kg CO_2]	1224.31
		AP	[kgSO_2.m⁻²]	0.1288	AP	[kg SO_2]	4.40110
		Δ OI3	[Pkt/m²]	44.78			
0.01 m Linoleum							
26.77	m² used	PEI n.e.	[MJ.m⁻²]	419.50	PEI n.e.	[MJ]	11230.02
		GWP	[kgCO_2.m⁻²]	9.87	GWP	[kg CO_2]	264.22
		AP	[kgSO_2.m⁻²]	0.1040	AP	[kg SO_2]	2.78408
		Δ OI3	[Pkt/m²]	29.50			
0.01 m Carpet							
37.13	m² used	PEI n.e.	[MJ.m⁻²]	82.44	PEI n.e.	[MJ]	3061.00
		GWP	[kgCO_2.m⁻²]	1.92	GWP	[kg CO_2]	71.29
		AP	[kgSO_2.m⁻²]	0.0183	AP	[kg SO_2]	0.67948
		Δ OI3	[Pkt/m²]	5.51			
0.01 m Laminate							
19.86	m² used	PEI n.e.	[MJ.m⁻²]	176.15	PEI n.e.	[MJ]	3498.34
		GWP	[kgCO_2.m⁻²]	0.88	GWP	[kg CO_2]	17.48
		AP	[kgSO_2.m⁻²]	0.0355	AP	[kg SO_2]	0.70503
		Δ OI3	[Pkt/m²]	10.75			

Influence of service life:

In this Scenario a lot of building components or parts of them are renovated. Table 52 shows how often the various materials would still have to be replaced during the 50-year period under consideration.

Table 52: Substitution during the period under consideration (source: illustration by the author)

Material		Age in 2020 [years]	Period of use - according to IBO [years]	Substitution during the period under consideration
Supporting structure		30	100	0
Windows	refurbished	0	35	1
Thermal insulation	refurbished	0	35	1
Plaster	refurbished	0	35	1
Floor covering: ceramic tiles	refurbished	0	50	0
Floor covering: linoleum	refurbished	0	25	1
Floor covering: laminate	refurbished	0	25	1
Floor covering: textile covering	refurbished	0	10	4

The number of necessary material deceptions as well as their disposal and the production of the new materials lead to the environmental influences listed in Table 53.

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Table 53: Impact of Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO₂.m⁻²]	Production GWP [kgCO₂.m⁻²]	** GWP [kg CO₂]	Removal AP [kgSO₂.m⁻²]	Production AP [kg SO₂.m⁻²]	** AP [kg SO₂]
Glazing (windows, door)	12.36	1	7.17	533.96	6,688.37	0.49	40.77	509.97	0.0031000	0.3112	3.88
Frame - plastic (windows, door)	6.60	1	0.44	1,101.87	7,275.25	40.37	- 33.03	48.44	0.0000420	0.3052	2.01
Plaster	248.88	1	4.72	29.76	8,581.38	0.34	3.15	868.59	0.0000884	0.0083	2.09
Floor covering: ceramic tiles	34.17	0	4.09	649.06	-	0.30	35.83	-	0.0018000	0.1288	0.00
Floor covering: linoleum	26.77	1	0.24	419.50	11,236.44	14.36	9.87	648.64	0.0000240	0.1040	2.78
Floor covering: laminate	37.13	1	0.15	176.15	6,546.02	11.80	0.88	470.81	0.0000140	0.0355	1.32
Floor covering: textile covering	19.86	4	1.61	82.44	6,676.93	4.05	1.92	474.26	0.0025000	0.0183	1.65
Thermal insulation - EPS (d=0,2m)	248.88	1	1.92	312.50	78,252.85	15.04	13.17	7,020.90	0.0009220	0.0470	11.93
Thermal insulation - XPS-R (d=0,2m)	150.42	1	3.55	755.82	114,224.44	23.64	31.95	8,361.85	0.0018770	0.1178	18.00
Sum					**239,481.67**			**18,403.46**			**43.67**

Influence of heating demand:

The heating demand of this Scenario is with 47.33 kWh.m^{-2}.a^{-1} much lower than in the Scenarios before. Therefore, the impact for heating this building is quite lower as it can be seen below – represented in annual values:

	Values per m²	Absolut values
Annual heating demand	47.33 kWh.m^{-2}	7,119.38 kWh
Impact		3,132.53 kg CO_2

Summary of whole Scenario:

In Table 54 the overall results for Scenario B.3 are listed.

Table 54: Sum for Scenario B.3 (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO₂]	AP [kg SO₂]	[kg CO₂]
Renovation measure	469,445.81	29,292.04	95.95	
Use (material exchages)	239,481.67	18,403.46	43.67	156,626.50
SUM	**708,927.48**	**47,695.50**	**139.62**	**156,626.50**

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3.14 House C / Scenario C

Energy Certificate:

Figure 42 provides the conducted Energy Certificate. This Energy Certificate shows that this building is – regarding the heating demand – a low energy house. In Austria, a low-energy house is defined as a building with a heating demand of less than or equal to 50 kWh per square meter and year. This fictitious building achieves a HBW_{SK} of 38.98 $kWh.m^{-2}.a^{-1}$. This corresponds to category B.

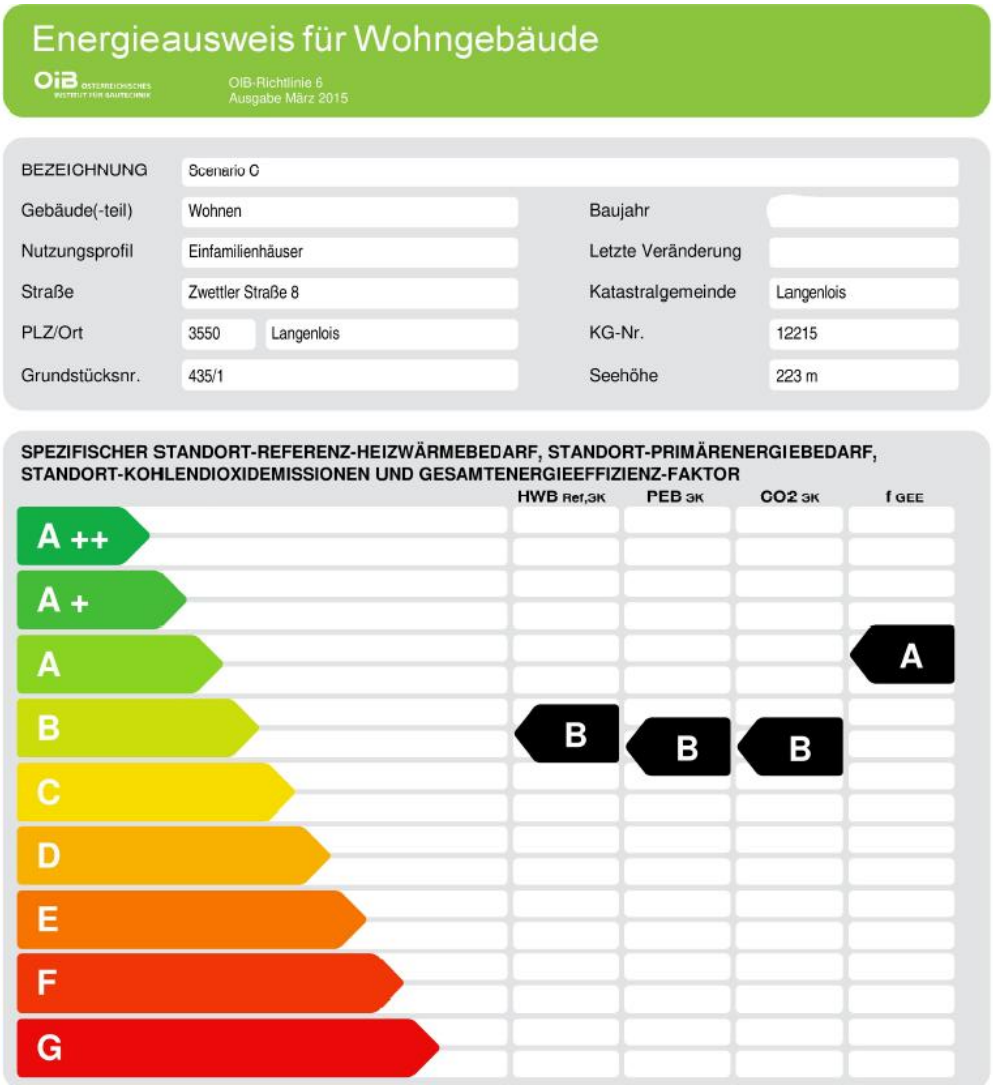

Figure 42: Energy Certificate Scenario C (source: illustration taken from ArchiPhysik based on the author's case study buildings)

Impact of production of used materials:

Table 55 to Table 59 show used materials and building components with their individual environmental impact for Scenario C. As for the previous Scenarios, the

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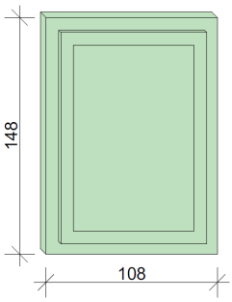
values per square meter, as well as the resulting individual values for the corresponding material are listed.

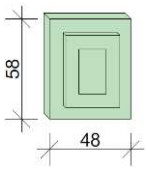
Table 55: Impact of production (Part 1) (source: illustration by the author)

Window 01 (big)



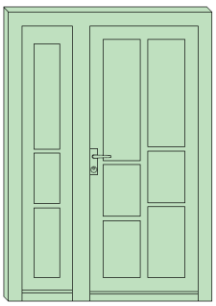
Triple glazing			Impact per m²			Absolut Impact		
11.30	m² used (10x1.13m²)	PEI n.e.	[MJ.m⁻²]	533.96		PEI n.e.	[MJ]	6033.75
		GWP	[$kgCO_2.m^{-2}$]	40.77		GWP	[kg CO_2]	460.70
		AP	[$kgSO_2.m^{-2}$]	0.31118		AP	[kg SO_2]	3.51633
		Δ OI3	[Pkt/m²]	66.08				
Wood frame (d = 0.1m) - spruce wood								
4.70	m² used (10x0.47m²)	PEI n.e.	[MJ.m⁻²]	1101.87		PEI n.e.	[MJ]	5178.79
		GWP	[$kgCO_2.m^{-2}$]	-33.026		GWP	[kg CO_2]	-155.22
		AP	[$kgSO_2.m^{-2}$]	0.30521		AP	[kg SO_2]	1.43449
		Δ OI3	[Pkt/m²]	71.92				

Window 03 (small)



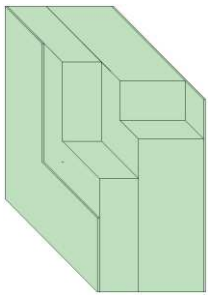
Triple glazing			Impact per m²			Absolut Impact		
0.22	m² used (2x0.11m²)	PEI n.e.	[MJ.m⁻²]	533.96		PEI n.e.	[MJ]	117.47
		GWP	[$kgCO_2.m^{-2}$]	40.77		GWP	[kg CO_2]	8.97
		AP	[$kgSO_2.m^{-2}$]	0.31118		AP	[kg SO_2]	0.06846
		Δ OI3	[Pkt/m²]	66.08				
Wood frame (d = 0.1m) - spruce wood								
0.34	m² used (2x0.17m²)	PEI n.e.	[MJ.m⁻²]	1101.87		PEI n.e.	[MJ]	374.64
		GWP	[$kgCO_2.m^{-2}$]	-33.026		GWP	[kg CO_2]	-11.23
		AP	[$kgSO_2.m^{-2}$]	0.30521		AP	[kg SO_2]	0.10377
		Δ OI3	[Pkt/m²]	71.92				

Entrance door



Triple glazing			Impact per m²			Absolut Impact		
0.84	m² used (1x0.84m²)	PEI n.e.	[MJ.m⁻²]	533.96		PEI n.e.	[MJ]	448.53
		GWP	[$kgCO_2.m^{-2}$]	40.77		GWP	[kg CO_2]	34.25
		AP	[$kgSO_2.m^{-2}$]	0.31118		AP	[kg SO_2]	0.26139
		Δ OI3	[Pkt/m²]	66.08				
Wood frame (d = 0.1m) - spruce wood								
1.56	m² used (1x1.56m²)	PEI n.e.	[MJ.m⁻²]	1101.87		PEI n.e.	[MJ]	1718.92
		GWP	[$kgCO_2.m^{-2}$]	-33.026		GWP	[kg CO_2]	-51.52
		AP	[$kgSO_2.m^{-2}$]	0.30521		AP	[kg SO_2]	0.47613
		Δ OI3	[Pkt/m²]	71.92				

Exterior walls



0.015 m Exterior plaster			Impact per m²			Absolut Impact		
248.88	m² used	PEI n.e.	[MJ.m⁻²]	43.80		PEI n.e.	[MJ]	10900.94
		GWP	[$kgCO_2.m^{-2}$]	4.65		GWP	[kg CO_2]	1157.29
		AP	[$kgSO_2.m^{-2}$]	0.012		AP	[kg SO_2]	2.9866
		Δ OI3	[Pkt/m²]	3.84				
0.3 m EPS								
248.88	m² used	PEI n.e.	[MJ.m⁻²]	468.76		PEI n.e.	[MJ]	116664.99
		GWP	[$kgCO_2.m^{-2}$]	19.76		GWP	[kg CO_2]	4917.87
		AP	[$kgSO_2.m^{-2}$]	0.0706		AP	[kg SO_2]	17.5709
		Δ OI3	[Pkt/m²]	28.33				

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Table 56: Impact of production (Part 2) (source: illustration by the author)

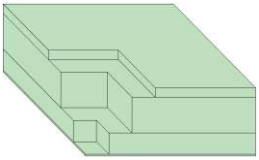
0.3 m Bricks (leightweight concrete bricks with expanded clay)

248.88	m² used	PEI n.e.	[MJ.m⁻²]	1056.21	PEI n.e.	[MJ]	262869.54
		GWP	[kgCO₂.m⁻²]	148.77	GWP	[kg CO₂]	37025.88
		AP	[kgSO₂.m⁻²]	0.3691	AP	[kg SO₂]	91.8616
		Δ OI3	[Pkt/m²]	109.22			

0.015 m Interior plaster

135.18	m² used	PEI n.e.	[MJ.m⁻²]	35.04	PEI n.e.	[MJ]	4736.71
		GWP	[kgCO₂.m⁻²]	3.72	GWP	[kg CO₂]	502.87
		AP	[kgSO₂.m⁻²]	0.0096	AP	[kg SO₂]	1.2977
		Δ OI3	[Pkt/m²]	3.07			

Ceiling to unheated attic



0.08 m Cement screed — Impact per m² / Absolut Impact

150.42	m² used	PEI n.e.	[MJ.m⁻²]	140.80	PEI n.e.	[MJ]	21179.14
		GWP	[kgCO₂.m⁻²]	15.36	GWP	[kg CO₂]	2310.45
		AP	[kgSO₂.m⁻²]	0.0384	AP	[kg SO₂]	5.7761
		Δ OI3	[Pkt/m²]	12.37			

0.0001 m Polyethylen foil board

150.42	m² used	PEI n.e.	[MJ.m⁻²]	90.07	PEI n.e.	[MJ]	13548.329
		GWP	[kgCO₂.m⁻²]	4.96	GWP	[kg CO₂]	746.08
		AP	[kgSO₂.m⁻²]	0.0235	AP	[kg SO₂]	3.5349
		Δ OI3	[Pkt/m²]	6.96			

0.3 m XPS - R

150.42	m² used	PEI n.e.	[MJ.m⁻²]	1133.73	PEI n.e.	[MJ]	170535.67
		GWP	[kgCO₂.m⁻²]	47.93	GWP	[kg CO₂]	7209.63
		AP	[kgSO₂.m⁻²]	0.1767	AP	[kg SO₂]	26.57921
		Δ OI3	[Pkt/m²]	69.34			

0.004 m Bitumen vapour barrier

150.42	m² used	PEI n.e.	[MJ.m⁻²]	225.28	PEI n.e.	[MJ]	33886.62
		GWP	[kgCO₂.m⁻²]	6.96	GWP	[kg CO₂]	1046.92
		AP	[kgSO₂.m⁻²]	0.0382	AP	[kg SO₂]	5.74604
		Δ OI3	[Pkt/m²]	13.76			

0.18 m Concrete

150.42	m² used	PEI n.e.	[MJ.m⁻²]	453.60	PEI n.e.	[MJ]	68230.51
		GWP	[kgCO₂.m⁻²]	60.04	GWP	[kg CO₂]	9031.22
		AP	[kgSO₂.m⁻²]	0.1296	AP	[kg SO₂]	19.49443
		Δ OI3	[Pkt/m²]	42.41			

0.015 m Interior plaster

150.42	m² used	PEI n.e.	[MJ.m⁻²]	35.04	PEI n.e.	[MJ]	5270.72
		GWP	[kgCO₂.m⁻²]	3.72	GWP	[kg CO₂]	559.56
		AP	[kgSO₂.m⁻²]	0.0096	AP	[kg SO₂]	1.44403
		Δ OI3	[Pkt/m²]	3.07			

Ceilings to ground

0.5 m Gravel — Impact per m² / Absolut Impact

150.42	m² used	PEI n.e.	[MJ.m⁻²]	72.00	PEI n.e.	[MJ]	10830.24
		GWP	[kgCO₂.m⁻²]	3.60	GWP	[kg CO₂]	541.51
		AP	[kgSO₂.m⁻²]	0.0000	AP	[kg SO₂]	0.00000
		Δ OI3	[Pkt/m²]	3.00			

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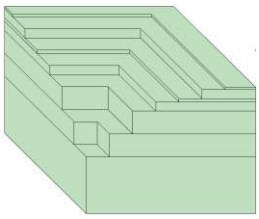
Table 57: Impact of production (Part 3) (source: illustration by the author)



0.2 m XPS-G 50							
150.42	m² used	PEI n.e.	[MJ.m⁻²]	711.09	PEI n.e.	[MJ]	106962.16
		GWP	[kgCO_2.m⁻²]	31.95	GWP	[kg CO_2]	4805.92
		AP	[kgSO_2.m⁻²]	0.1180	AP	[kg SO_2]	17.74956
		Δ OI3	[Pkt/m²]	44.76			
0.2 m Concrete							
150.42	m² used	PEI n.e.	[MJ.m⁻²]	504.00	PEI n.e.	[MJ]	75811.68
		GWP	[kgCO_2.m⁻²]	66.72	GWP	[kg CO_2]	10036.02
		AP	[kgSO_2.m⁻²]	0.1440	AP	[kg SO_2]	21.66048
		Δ OI3	[Pkt/m²]	47.12			
0.0001 m Sealing							
150.42	m² used	PEI n.e.	[MJ.m⁻²]	8.17	PEI n.e.	[MJ]	1228.93
		GWP	[kgCO_2.m⁻²]	0.23	GWP	[kg CO_2]	34.60
		AP	[kgSO_2.m⁻²]	0.0013	AP	[kg SO_2]	0.19555
		Δ OI3	[Pkt/m²]	0.48			
0.08 m EPS granulate levelling compound							
150.42	m² used	PEI n.e.	[MJ.m⁻²]	113.47	PEI n.e.	[MJ]	17068.16
		GWP	[kgCO_2.m⁻²]	8.65	GWP	[kg CO_2]	1301.13
		AP	[kgSO_2.m⁻²]	0.0204	AP	[kg SO_2]	3.06857
		Δ OI3	[Pkt/m²]	7.94			
0.03 m Footfall sound insulation							
150.42	m² used	PEI n.e.	[MJ.m⁻²]	32.63	PEI n.e.	[MJ]	4908.20
		GWP	[kgCO_2.m⁻²]	1.37	GWP	[kg CO_2]	206.08
		AP	[kgSO_2.m⁻²]	0.0049	AP	[kg SO_2]	0.73706
		Δ OI3	[Pkt/m²]	1.97			
0.0001 m PE-foil							
150.42	m² used	PEI n.e.	[MJ.m⁻²]	90.07	PEI n.e.	[MJ]	13548.33
		GWP	[kgCO_2.m⁻²]	4.96	GWP	[kg CO_2]	746.08
		AP	[kgSO_2.m⁻²]	0.0235	AP	[kg SO_2]	3.53487
		Δ OI3	[Pkt/m²]	6.96			
0.08 m Screed							
150.42	m² used	PEI n.e.	[MJ.m⁻²]	140.80	PEI n.e.	[MJ]	21179.14
		GWP	[kgCO_2.m⁻²]	15.36	GWP	[kg CO_2]	2310.45
		AP	[kgSO_2.m⁻²]	0.0384	AP	[kg SO_2]	5.77613
		Δ OI3	[Pkt/m²]	12.37			
0.02 m Tiles							
34.17	m² used	PEI n.e.	[MJ.m⁻²]	649.06	PEI n.e.	[MJ]	22178.38
		GWP	[kgCO_2.m⁻²]	35.83	GWP	[kg CO_2]	1224.31
		AP	[kgSO_2.m⁻²]	0.1288	AP	[kg SO_2]	4.40110
		Δ OI3	[Pkt/m²]	44.78			
0.01 m Linoleum							
26.77	m² used	PEI n.e.	[MJ.m⁻²]	419.50	PEI n.e.	[MJ]	11230.02
		GWP	[kgCO_2.m⁻²]	9.87	GWP	[kg CO_2]	264.22
		AP	[kgSO_2.m⁻²]	0.1040	AP	[kg SO_2]	2.78408
		Δ OI3	[Pkt/m²]	29.50			
0.01 m Carpet							
37.13	m² used	PEI n.e.	[MJ.m⁻²]	82.44	PEI n.e.	[MJ]	3061.00
		GWP	[kgCO_2.m⁻²]	1.92	GWP	[kg CO_2]	71.29
		AP	[kgSO_2.m⁻²]	0.0183	AP	[kg SO_2]	0.67948
		Δ OI3	[Pkt/m²]	5.51			
0.01 m Laminate							
19.86	m² used	PEI n.e.	[MJ.m⁻²]	176.15	PEI n.e.	[MJ]	3498.34
		GWP	[kgCO_2.m⁻²]	0.88	GWP	[kg CO_2]	17.48
		AP	[kgSO_2.m⁻²]	0.0355	AP	[kg SO_2]	0.70503
		Δ OI3	[Pkt/m²]	10.75			

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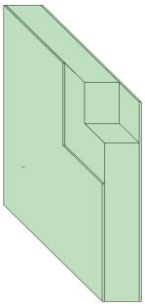
Table 58: Impact of production (Part 4) (source: illustration by the author)

Interior walls 01 - 25



0.015 m Interior plaster

61.42	m² used	PEI n.e.	[MJ.m⁻²]	35.04	PEI n.e.	[MJ]	2152.16
		GWP	[kgCO₂.m⁻²]	3.72	GWP	[kg CO₂]	228.48
		AP	[kgSO₂.m⁻²]	0.0096	AP	[kg SO₂]	0.5896
		Δ OI3	[Pkt/m²]	3.07			

0.25 m Bricks (hollow concrete blocks)

61.42	m² used	PEI n.e.	[MJ.m⁻²]	351.00	PEI n.e.	[MJ]	21558.42
		GWP	[kgCO₂.m⁻²]	43.65	GWP	[kg CO₂]	2680.98
		AP	[kgSO₂.m⁻²]	0.0900	AP	[kg SO₂]	5.5278
		Δ OI3	[Pkt/m²]	30.98			

0.015 m Interior plaster

61.42	m² used	PEI n.e.	[MJ.m⁻²]	35.04	PEI n.e.	[MJ]	2152.16
		GWP	[kgCO₂.m⁻²]	3.72	GWP	[kg CO₂]	228.48
		AP	[kgSO₂.m⁻²]	0.0096	AP	[kg SO₂]	0.5896
		Δ OI3	[Pkt/m²]	3.07			

Interior walls 02 - 10

0.015 m Interior plaster

61.42	m² used	PEI n.e.	[MJ.m⁻²]	35.04	PEI n.e.	[MJ]	2152.16
		GWP	[kgCO₂.m⁻²]	3.72	GWP	[kg CO₂]	228.48
		AP	[kgSO₂.m⁻²]	0.0096	AP	[kg SO₂]	0.5896
		Δ OI3	[Pkt/m²]	3.07			

0.1 m Bricks (hollow concrete blocks)

61.42	m² used	PEI n.e.	[MJ.m⁻²]	140.40	PEI n.e.	[MJ]	8623.37
		GWP	[kgCO₂.m⁻²]	17.46	GWP	[kg CO₂]	1072.39
		AP	[kgSO₂.m⁻²]	0.0360	AP	[kg SO₂]	2.2111
		Δ OI3	[Pkt/m²]	12.39			

0.015 m Interior plaster

61.42	m² used	PEI n.e.	[MJ.m⁻²]	35.04	PEI n.e.	[MJ]	2152.16
		GWP	[kgCO₂.m⁻²]	3.72	GWP	[kg CO₂]	228.48
		AP	[kgSO₂.m⁻²]	0.0096	AP	[kg SO₂]	0.5896
		Δ OI3	[Pkt/m²]	3.07			

Roof

0.02 m Roof tile			Impact per m²			Absolut Impact	
198.47	m² used	PEI n.e.	[MJ.m⁻²]	161.16	PEI n.e.	[MJ]	31985.43
		GWP	[kgCO₂.m⁻²]	8.77	GWP	[kg CO₂]	1740.58
		AP	[kgSO₂.m⁻²]	0.0238	AP	[kg SO₂]	4.7236
		Δ OI3	[Pkt/m²]	10.01			

0.04 m Lathing (wood - spruce)

7.32	m² used	PEI n.e.	[MJ.m⁻²]	1.78	PEI n.e.	[MJ]	13.0296
		GWP	[kgCO₂.m⁻²]	-1.34	GWP	[kg CO₂]	-9.81
		AP	[kgSO₂.m⁻²]	0.0005	AP	[kg SO₂]	0.0037
		Δ OI3	[Pkt/m²]	-0.10			

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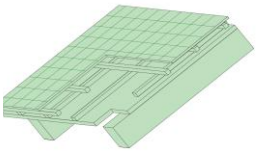
Table 59: Impact of production (Part 5) (source: illustration by the author)



0.001 m Polymeric bitumen sealing sheet

198.47	m² used	PEI n.e.	[MJ.m⁻²]	45.75	PEI n.e.	[MJ]	9080.00
		GWP	[$kgCO_2.m^{-2}$]	0.90	GWP	[kg CO_2]	178.62
		AP	[$kgSO_2.m^{-2}$]	0.0061	AP	[kg SO_2]	1.21067
		Δ OI3	[Pkt/m²]	2.49			

0.04 m Counterbattening

11.92	m² used	PEI n.e.	[MJ.m⁻²]	1.78	PEI n.e.	[MJ]	21.22
		GWP	[$kgCO_2.m^{-2}$]	-1.34	GWP	[kg CO_2]	-15.97
		AP	[$kgSO_2.m^{-2}$]	0.0005	AP	[kg SO_2]	0.00596
		Δ OI3	[Pkt/m²]	-0.10			

0.04 m Wooden formwork

7.32	m² used	PEI n.e.	[MJ.m⁻²]	44.64	PEI n.e.	[MJ]	326.76
		GWP	[$kgCO_2.m^{-2}$]	-33.72	GWP	[kg CO_2]	-246.83
		AP	[$kgSO_2.m^{-2}$]	0.0144	AP	[kg SO_2]	0.10541
		Δ OI3	[Pkt/m²]	-2.21			

0.001 m Aluminium vapour barrier

198.47	m² used	PEI n.e.	[MJ.m⁻²]	1545.40	PEI n.e.	[MJ]	306715.54
		GWP	[$kgCO_2.m^{-2}$]	92.68	GWP	[kg CO_2]	18394.20
		AP	[$kgSO_2.m^{-2}$]	0.4397	AP	[kg SO_2]	87.26726
		Δ OI3	[Pkt/m²]	125.59			

0.24 m Rafters

26.82	m² used	PEI n.e.	[MJ.m⁻²]	18.74	PEI n.e.	[MJ]	502.61
		GWP	[$kgCO_2.m^{-2}$]	-14.16	GWP	[kg CO_2]	-379.77
		AP	[$kgSO_2.m^{-2}$]	0.0060	AP	[kg SO_2]	0.16092
		Δ OI3	[Pkt/m²]	-0.94			

Influence of service life:

Since all materials are newly produced for this Scenario, the calculation of their service life begins at the time of construction. This means that materials may have to be exchanged less frequently during the period under consideration. The number of replacements required is listed in Table 60 in the far-right column.

Table 60: Substitution during the period under consideration (source: illustration by the author)

Material		Age in 2020 [years]	Period of use - according to IBO [years]	Substitution during the period under consideration
Supporting structure	newly constructed	0	100	0
Windows	newly constructed	0	35	1
Thermal insulation	newly constructed	0	35	1
Plaster	newly constructed	0	35	1
Floor covering: ceramic tiles	newly constructed	0	50	0
Floor covering: linoleum	newly constructed	0	25	1
Floor covering: laminate	newly constructed	0	25	1
Floor covering: textile covering	newly constructed	0	10	4

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Table 61 represents the impact of changed materials during the use-phase of 50 years.

Table 61: Impact of Use-phase in regard to materials life span (source: illustration by the author)

Material	Sum of areas [m²]	Substitution	Removal PEI n.e. [MJ.m⁻²]	Production PEI n.e. [MJ.m⁻²]	** PEI n.e. [MJ]	Removal GWP [kgCO₂.m⁻²]	Production GWP [kgCO₂.m⁻²]	** GWP [kg CO₂]	Removal AP [kgSO₂.m⁻²]	Production AP [kg SO₂.m⁻²]	** AP [kg SO₂]
Glazing (windows, door)	12.36	1	7.17	533.96	6,688.37	0.49	40.77	509.97	0.0031000	0.3112	3.88
Frame - plastic (windows, door)	6.60	1	0.44	1,101.87	7,275.25	40.37	- 33.03	48.44	0.0000420	0.3052	2.01
Plaster	248.88	1	4.72	43.80	12,075.66	0.34	4.65	1,241.91	0.0000884	0.0120	3.01
Floor covering: ceramic tiles	34.17	0	4.09	649.06	-	0.30	35.83	-	0.0018000	0.1288	0.00
Floor covering: linoleum	26.77	1	0.24	419.50	11,236.44	14.36	9.87	648.64	0.0000240	0.1040	2.78
Floor covering: laminate	37.13	1	0.15	176.15	6,546.02	11.80	0.88	470.81	0.0000140	0.0355	1.32
Floor covering: textile covering	19.86	4	1.61	82.44	6,676.93	4.05	1.92	474.26	0.0025000	0.0183	1.65
Thermal insulation - EPS (0,3m)	248.88	1	2.88	468.76	117,381.76	22.56	19.76	10,532.60	0.0013830	0.0706	17.92
Thermal insulation - XPS-R (0,3m)	150.42	1	5.33	1,133.73	171,337.41	35.46	47.93	12,543.52	0.0028160	0.1767	27.00
Sum					**339,217.83**			**26,470.16**			**59.58**

<u>Influence of heating demand:</u>

The new constructed building – “House C” – achieved an annual heating demand of 38.98 kWh.m^{-2}.a^{-1}. The heated gross floor area is the same as that of House B. It is therefore 150.42m². This means that in this Scenario the following amount of CO_2 is emitted during the period under consideration for heating the building:

	Values per m²	Absolut values
Annual heating demand	38.98 kWh.m^{-2}	5,863.37 kWh
Impact		2,579.88 kg CO_2

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Summary of whole Scenario:

In Table 62 a summary for Scenario C is shown. The impact for producing the materials, the impact of material exchange during the considered 50-year use-phase as well as the influence of heating the building for 50 years is displayed.

Table 62: Sum for Scenario C (source: illustration by the author)

	Materials			Heating
	PEI n.e. [MJ]	GWP [kg CO_2]	AP [kg SO_2]	[kg CO_2]
Renovation measure	1,400,634.82	110,681.14	347.02	
Use (material exchages)	339,217.83	26,470.16	59.58	128,994.00
SUM	**1,739,852.65**	**137,151.30**	**406.60**	**128,994.00**

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4 DISCUSSION

4.1 Overview

In this chapter, the derived results of the individual scenarios will now be compared. This is done in several steps, separating in short-term impact (immediate impact by retrofit measure) and long-term impact (over 50 years of occupancy and use).

First step: Impact of renovation measure (short-term)

At the beginning, the environmental influences caused by the actual remediation measures are compared. For the existing buildings, this included both the removal of some existing materials and the production of new materials used. For the new building, all necessary materials for its construction were calculated.

Second step: Impact of period under consideration regarding necessary material exchange (long-term)

The next step is to compare the environmental influences that arise from a necessary exchange of materials during the period under consideration of 50 years.

Third step: Impact of period under consideration regarding heating (long-term)

In a further step, the effects on the environment in terms of the operation of the building are compared.

At the end of this chapter, all individual steps are added up and compared.

4.1.1 Impact of renovation measure

Looking at the step where the renovation or the new construction takes place, the following graphs (Figure 43, Figure 44, and Figure 45) clearly show that the new construction – Scenario C – has the highest environmental impact. This is kind of obvious due to the high material input. Although there is the fact that for this case study, which deals with the background of urban sprawl, no old building has to be demolished before erecting the new one, a big amount of materials is needed to erect a whole building from scratch. While only individual materials were removed and added in the renovation scenarios, all materials of all construction parts had to be produced for the newly constructed building. This finding applies to all three OI3 eco-indicators.

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With regard to the category of global warming potential (GWP) (Figure 44), it can be seen that in Scenarios A.2.2 und B.2.2 a negative value was achieved by using wood fiber insulation boards instead of EPS and XPS. However, the amount of non-renewable energy resource requirement is slightly higher in these cases where wood fiber insulation boards were used for insulating the walls and the ceiling to the unheated attic. The same applies to the indicator of acidification potential (AP) (Figure 45).

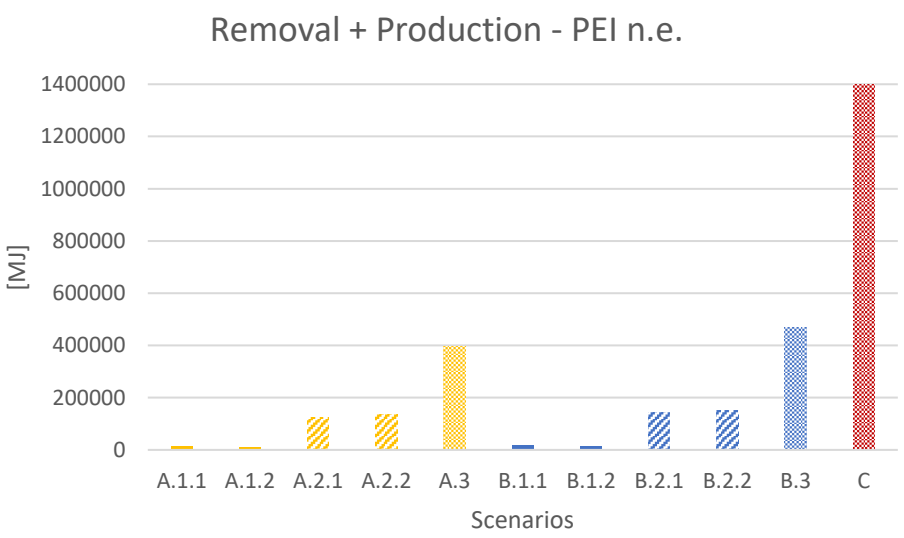

Figure 43: Results renovation measure – PEI n.e. (source: illustration by the author)

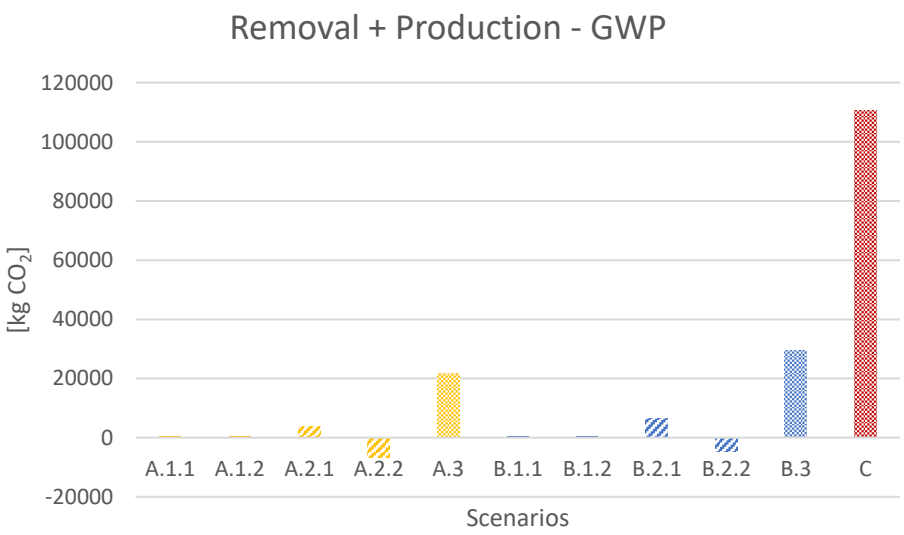

Figure 44: Results renovation measure – GWP (source: illustration by the author)

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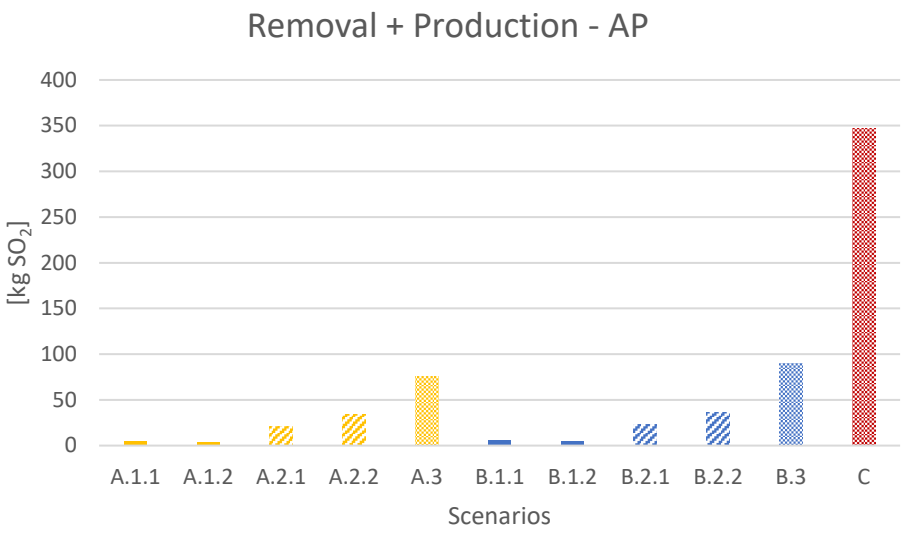

Figure 45: Results renovation measure – AP (source: illustration by the author)

The recycling potential in the disposal of materials has been neglected. A “worst-case”-scenario was therefore assumed in this respect.

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4.1.2 Impact of period under consideration regarding necessary material exchange

The outcome of needed non-renewable energy due to material exchanges during the period under consideration is presented in Figure 46. The other two OI3 indicators are shown in Figure 47 and Figure 48.

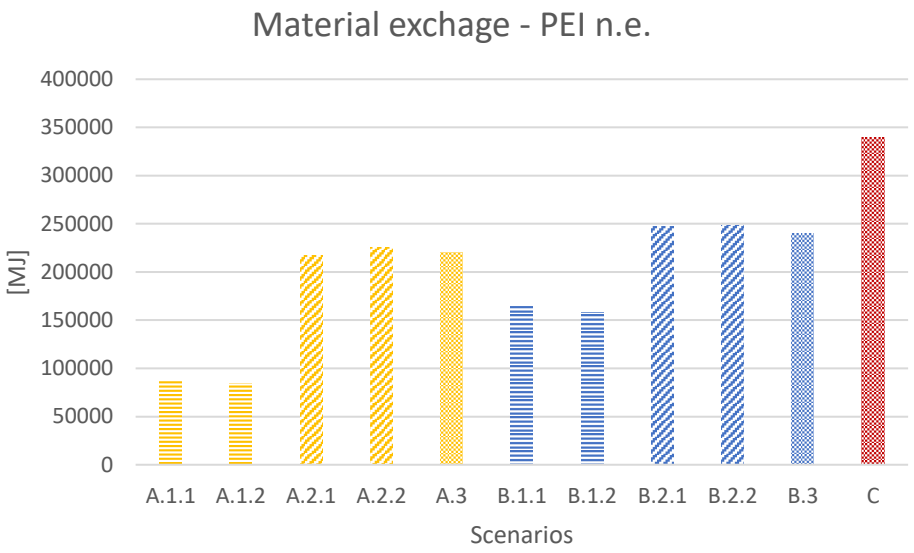

Figure 46: Results material exchange – PEI n.e. (source: illustration by the author)

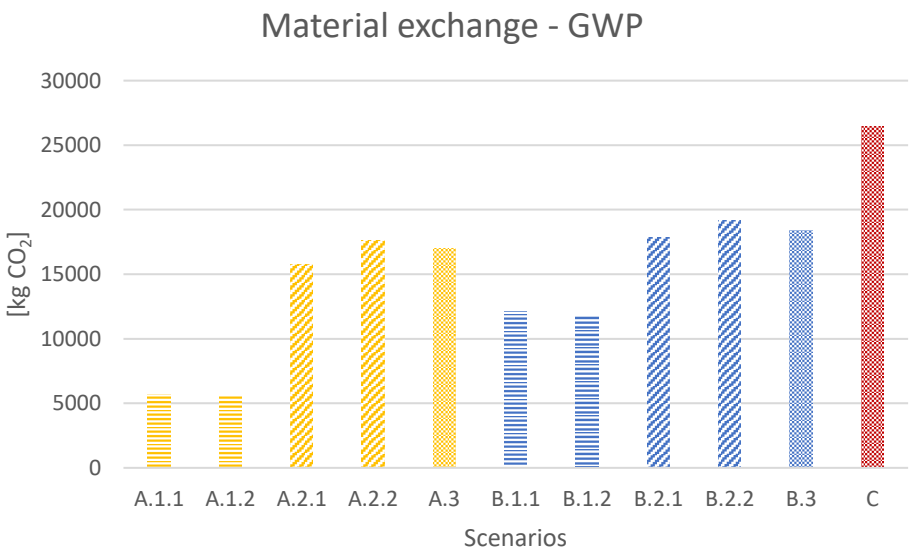

Figure 47: Results material exchange – GWP (source: illustration by the author)

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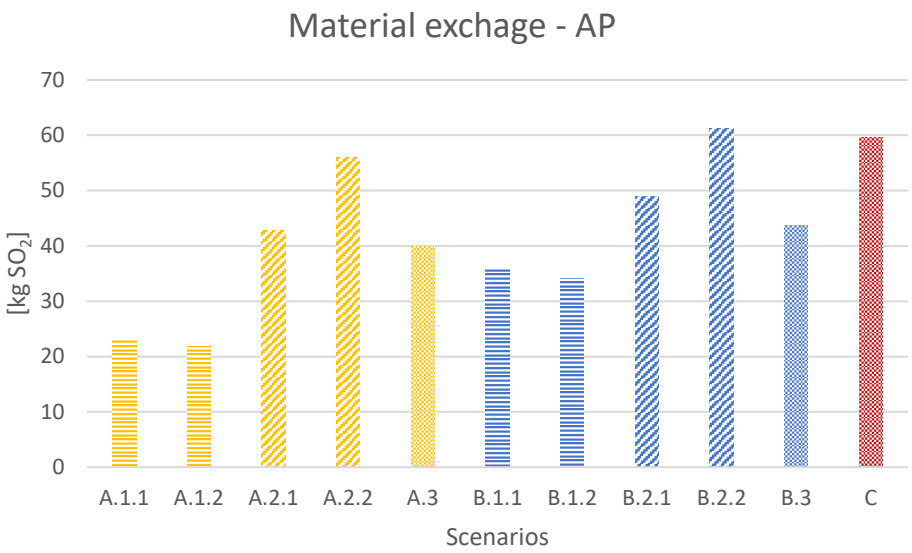

Figure 48: Results material exchange – AP (source: illustration by the author)

4.1.3 Impact of period under consideration regarding heating demand

In Figure 49 the annual heating demand of the two existing buildings and all the conducted Scenarios, including the newly constructed building, are shown.

It has been shown that simply replacing windows in both the older House A and the newer House B has brought hardly any improvement in terms of heating requirement. Completely different results can be achieved by insulating the walls and the top floor. In the case of the older building, which currently has no insulation, the heating requirement has been massively reduced. The newer building of 1990 already had a thin layer with insulation in its original state. For this reason, the reduction is not quite as drastic here. Nevertheless, the thicker insulation layers have successfully reduced the heating requirement and thus also the amount of CO_2 produced. The newly constructed building stands out because it has by far the lowest heating requirement.

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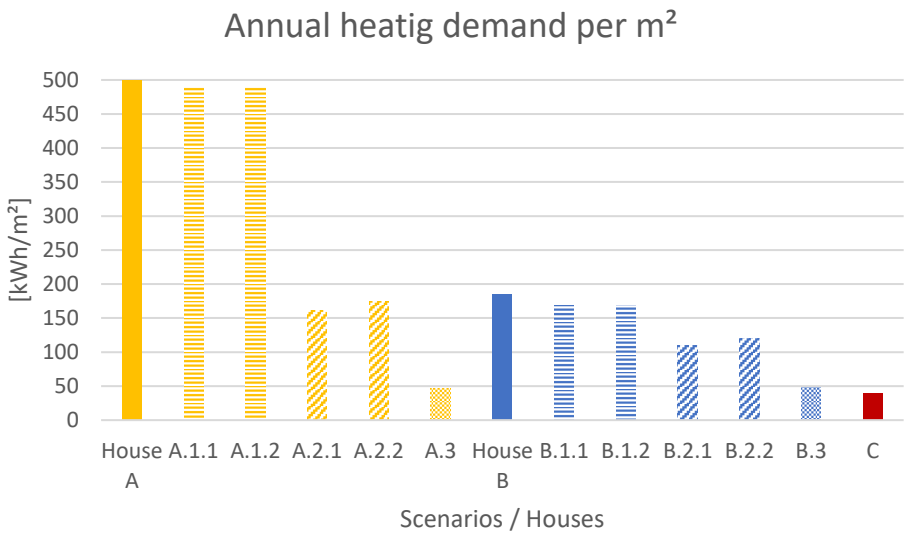

Figure 49: Annual heating demand per m² - all Scenarios (source: illustration by the author)

The following graph (Figure 50) shows the CO_2 emissions of the individual Scenarios for heating for 50 years. As these values are directly related to the respective heating demand, the same course as in the figure above can be seen here.

As the environmental impact over the lifetime of the building is very important, any renovation should try to reduce the heating demand of the building as much as possible. Figure 50 also clarifies that simply replacing windows does not have a major impact on the reduction of CO_2. This applies to both the very old existing building and the newer one. Almost as much CO_2 is produced as in the respective existing buildings.

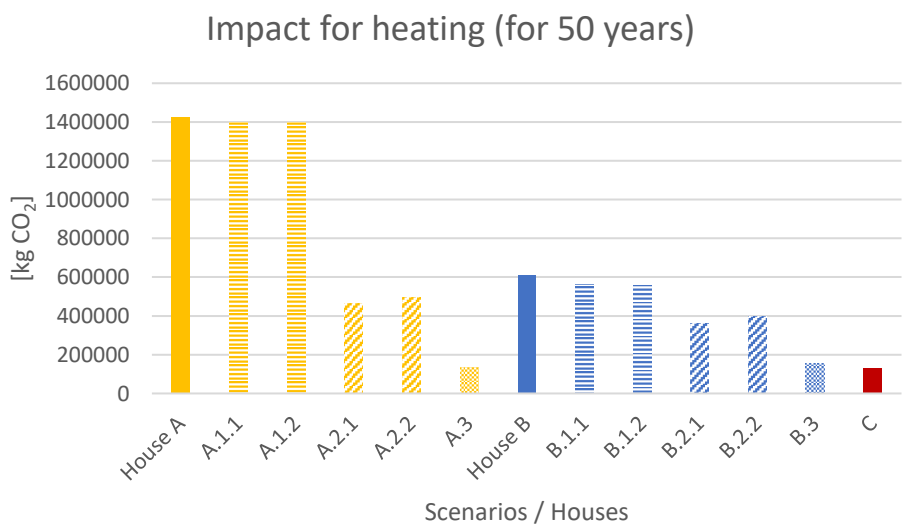

Figure 50: Results impact for heating (source: illustration by the author)

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4.1.4 Sum of all individual steps

The overall results regarding non-renewable energy resource requirement (PEI n.e.) are presented in Table 63 as well as in Figure 51. This study has shown that the construction of a new building and its 50-year operation requires a much higher proportion of non-renewable energy than the various renovation options.

It is noticeable that the more materials are used, the higher the amount of PEI n.e. For Scenarios A.1.1, A.1.2, B.1.1 and B.1.2, where only the windows were changed, only 5 to 10 percent of the amount of Scenario C (new construction) was needed. But even the more comprehensive remediation in Scenario A3 and B3 caused less than half of the emission of Scenario C.

Table 63: Overall Results: PEI n.e. (source: illustration by the author)

	PEI n.e. MJ
Scenario A.1.1	99,710.30
Scenario A.1.2	93,694.39
Scenario A.2.1	341,410.64
Scenario A.2.2	359,636.55
Scenario A.3	615,073.78
Scenario B.1.1	179,485.56
Scenario B.1.2	170,423.82
Scenario B.2.1	390,046.22
Scenario B.2.2	398,619.66
Scenario B.3	708,927.48
Scenario C	1,739,852.65

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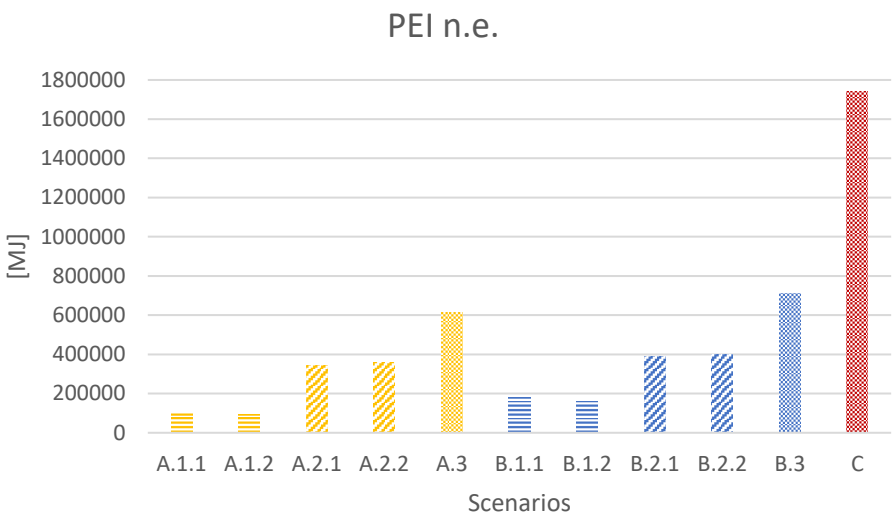

Figure 51: Overall Results: PEI n.e. (source: illustration by the author)

If the amount of CO_2 produced because of heating is disregarded, the newly constructed building shows the worst performance. The enormous amount of materials needed also releases an enormous amount of CO_2. The graph in Figure 52 illustrates that.

The values displayed in Table 64 also illustrate this recognition. The shown values in the table represent the amount of CO_2 in kilogram for each Scenario.

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Table 64: Overall Results: GWP without heating (source: illustration by the author)

	GWP without heating kg CO_2
Scenario A.1.1	6,203.32
Scenario A.1.2	5,985.82
Scenario A.2.1	19,640.96
Scenario A.2.2	11,071.46
Scenario A.3	38,757.12
Scenario B.1.1	12,790.96
Scenario B.1.2	12,376.70
Scenario B.2.1	24,315.73
Scenario B.2.2	14,451.80
Scenario B.3	47,695.50
Scenario C	137,151.29

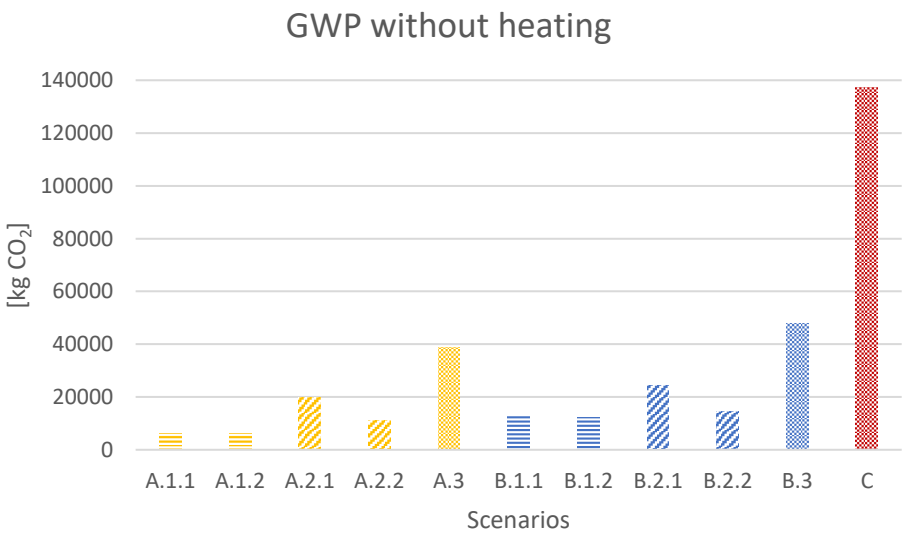

Figure 52: Overall Results: GWP without heating (source: illustration by the author)

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If the amount of CO_2 from the heating system is included in the results for global warming potential (GWP), the whole thing looks completely different. It can be clearly seen that the required heating energy of a building has a very strong effect on the result.

The worst of all are the window-exchange scenarios of the very old building, which is illustrated in Figure 53. This is due to the very high heating requirements of the old building, which could hardly be reduced by only replacing the windows.

But even here the scenarios A3 and B3 show a better performance than the new construction in Scenario C. This illustrates once again that extensive thermal refurbishment of an existing building is preferable to a completely new erected building. Especially Table 65 where the exact amount of kg CO_2 are displayed can clearly illustrate that fact.

Table 65: Overall Results: GWP including heating (source: illustration by the author)

	GWP including heating kg CO_2
Scenario A.1.1	1,401,724.32
Scenario A.1.2	1,405,993.32
Scenario A.2.1	481,804.46
Scenario A.2.2	507,956.96
Scenario A.3	173,588.12
Scenario B.1.1	577,115.46
Scenario B.1.2	568,593.70
Scenario B.2.1	385,155.23
Scenario B.2.2	413,678.30
Scenario B.3	204,322.00
Scenario C	266,145.29

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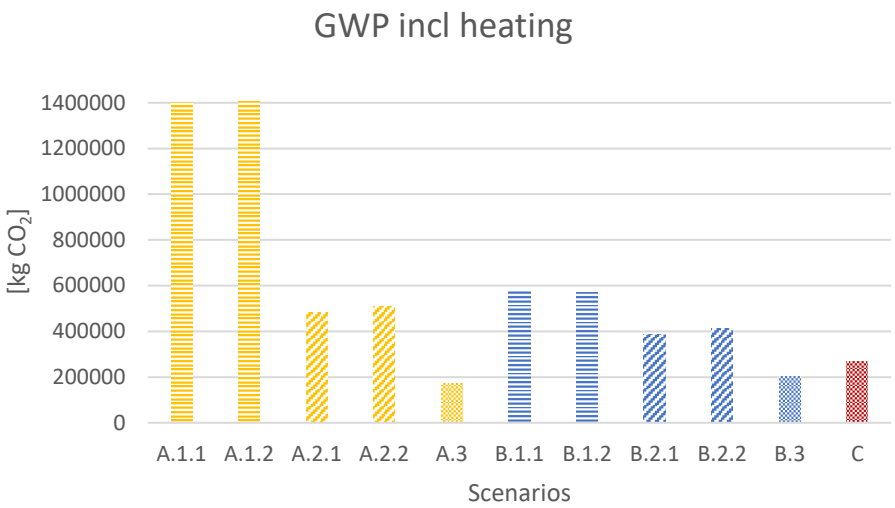

Figure 53: Overall Results: GWP including heating (source: illustration by the author)

The results of the category acidification potential are displayed graphically in Figure 54 and in Table 66 in tabular form. Here, too, it can be clearly seen that a much larger quantity of SO_2 is caused by the new construction than by the renovation measures.

Table 66: Overall Results: AP (source: illustration by the author)

	AP kg SO_2
Scenario A.1.1	27.86
Scenario A.1.2	25.82
Scenario A.2.1	63.66
Scenario A.2.2	90.20
Scenario A.3	116.51
Scenario B.1.1	42.03
Scenario B.1.2	39.26
Scenario B.2.1	74.66
Scenario B.2.2	100.65
Scenario B.3	139.62
Scenario C	406.60

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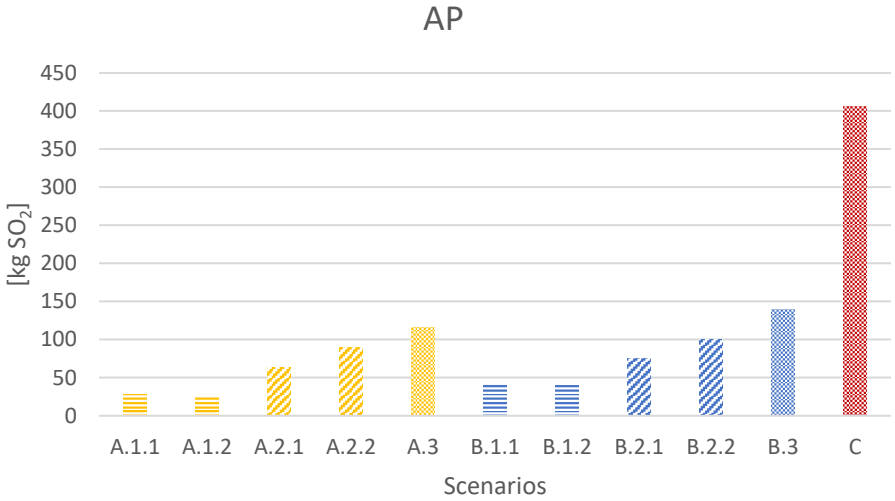

Figure 54: Overall Results: AP (source: illustration by the author)

4.1.5 Summary

In Figure 55 the previously shown results are summarized and displayed as relative ratios in percent. The relative ratio to the highest value of each category was calculated. The highest value is always displayed as a full circular ring at 100 percent. This graph shows clearly that the new construction performs mostly worse than the renovation scenarios. The only exception is the category of global warming potential (GWP) if the amount of CO_2 for heating the rooms for 50 years is included.

But even there less CO_2 is produced by the two existing buildings which were extensively thermally refurbished (Scenario A.3 and Scenario B.3).

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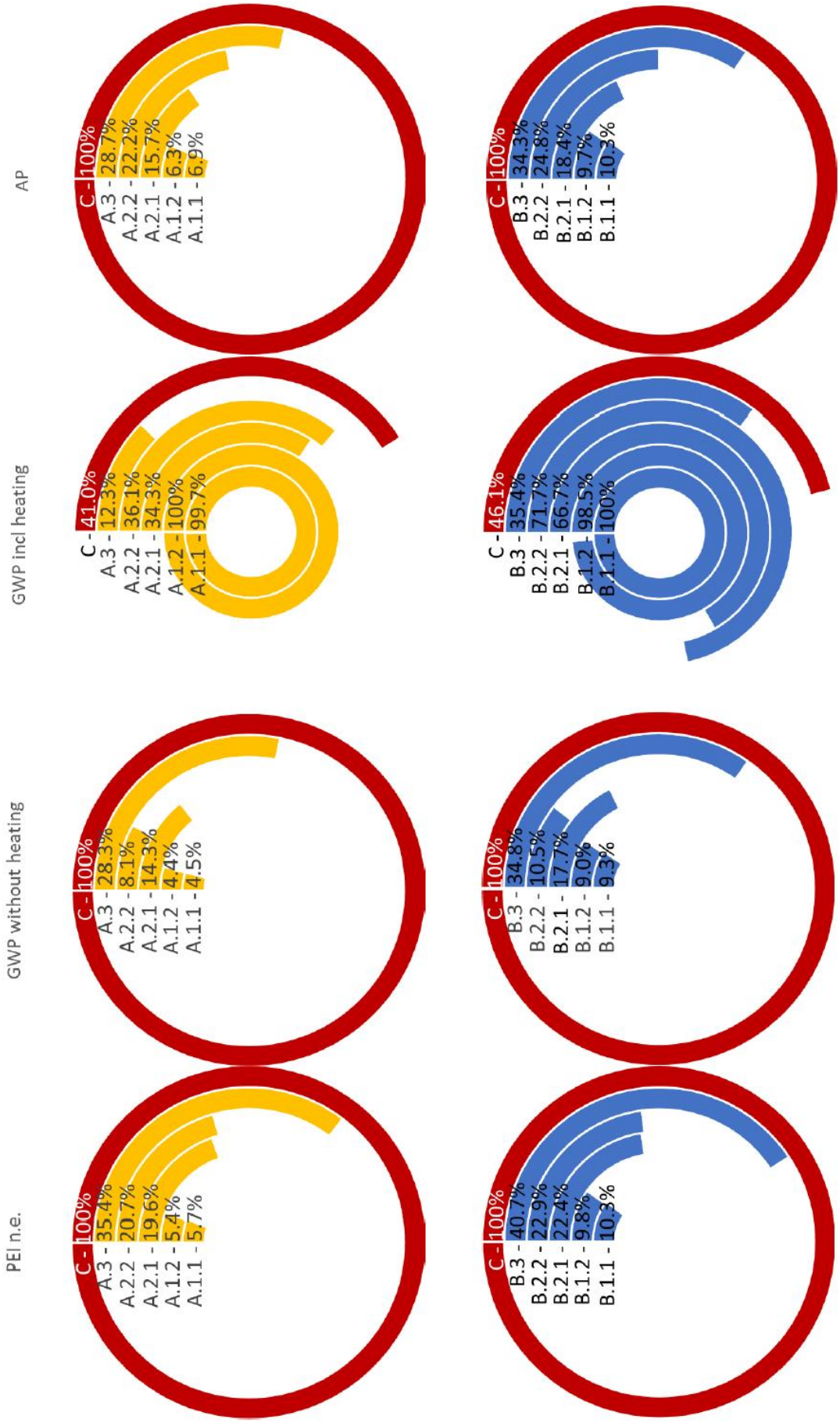

Figure 55: Summary of impact categories and Scenarios (source: illustration by the author)

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4.2 Limitations of this study

For the two existing buildings ("A", "B"), which have been used for this work, the layered component structures were largely known. For this reason, these superstructures could be used as input data into ArchiPhysik. The tool - in return – provided derived U-values. These U-values have been used for the calculations in this contribution. These U-values are based on conductivity values taken from the catalogues integrated in Archiphysik. The selection of conductivity values has been done by the author based on the materials that have been found in the constituting building components. Needless to say, there is a wide variety of building materials and even more range in these material conductivity values. As such, the U-values are rough estimates of the thermal performance of these components.

The guideline (OIB 6-Leitfaden 2019) published together with the OIB guideline 6 (OIB 6 2019) provides so called Default U-values that can be used if nothing is known about the constituent layers of superstructures. These values regularly are considered as average values, not as worst case values.

On the basis of the exterior wall of house A in this work it can be seen that large deviations between U-values derived from the calculation of the layers based on measured thickness and selected conductivity values and the default U-Values can occur.

The calculation resulted in an U-value of 2.387 [$W.m^{-2}.K^{-1}$], while the default vale for the same wall based on the guideline accounts for 1.55 [$W.m^{-2}.K^{-1}$].

Although this deviation would not affect the resulting heating demand class of the energy certificate, the absolute heating demand value would be significantly reduced from 499.55 [$kWh.m^{-2}.a^{-1}$] to 391.29 [$kWh.m^{-2}.a^{-1}$]. Of course, the improvement measures would then also result in different heating demand values. Given these enormous deviations, the current practice of using the default values whenever there is no further information has to be critically questioned in future research efforts.

To be on secure pages, the layered construction has been used in this work. Given that the retrofit scenarios outperform the new building even with this worst-case assumption, the large potential of existing structures can be seen.

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5 CONCLUSION

The focus of this study was the ecological and economical comparison of different refurbishment options with a new building. Since the problem of urban sprawl is becoming increasingly prevalent in many cities, this study works with this background. This is also the reason why no old building was demolished in the Scenario of the new construction in these investigations.

One might think that the new construction scenario would perform best by not demolishing an existing building before. However, the results presented in this paper have shown, that, from an ecological point of view, extensive thermal refurbishment of an existing building is preferable to a new construction. A remediation generally contributes significantly to the conservation of resources. Fewer materials are used than for a completely new building.

It should be noted, however, that simply replacing windows often does not lead to the desired improvement, since in the long run the heating requirements and the CO_2 emissions caused by them have a strong influence on the ecological performance.

This study has shown that it is worthwhile to preserve even very old buildings. If these buildings are thermally renovated, energy can be saved, and existing resources can be used. It is always essential to check whether the supporting structure is still in good condition and can withstand the higher dead loads of the stored materials due to the renovation.

In this case study the supporting structure of both existing buildings were still in good condition. Before actually taking remedial action, this would of course have to be clarified by a specialist.

The major research questions of this master thesis can therefore be answered as follows:

To perform a holistic comparison between existing buildings (in their original shape and potential retrofit scenarios) with a yet-to-be-built building a large number of aspects have to be considered. For instance, the point in time where retrofit measures are conducted, especially in comparison to the buildings' life span needs to be carefully considered. It is not sufficient to consider only those measures that arise during the step of the new construction or the retrofit of an old building. It is important to also include the following use (operation) of the buildings. This includes, on the one hand, the necessary material exchange (replacement / required renewal of components) during this period as well as the heating requirements over a selected

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period of time. As other studies have already found, the use phase has a major impact on the results. In this case study the retrofit of existing buildings always showed a better performance except once. If both heating demand and global warming potential is considered, the yet-to-be-built building showed a better performance as the retrofit scenarios – at least if an occupancy period of 50 years is considered, as was the case in this study.

One problem with such analyses is, that, on the one hand, the exact materials of the existing buildings are often not exactly known, and, on the other hand, it is not possible to know which materials will be used in the future. Even if the composition is known in detail, the physical properties are regularly not available, so that assumptions have to be made. Needless to say, there is a range of values for major physical properties such as conductivity, specific heat, density, or water vapor diffusion resistance. Often one has no other choice than to make qualified assumptions based on available data of most similar materials known.

Another aspect that is difficult to consider in recent years is the impact of climate change. In this master thesis the climate file was kept constant, which seems a viable way to provide a comparison. An adaptive change of the used climate data files would be possible, but highly speculative and presumably influence the general meaningfulness of the results.

Nevertheless, the present methodology can be considered as a useful way for finding out which measures have less impact on the environment and should be used even more often in future to avoid additional unnecessary environmental pollution.

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5.1 Future Research

In this study, different renovation measures were virtually applied on two existing buildings of different age in comparison with a yet-to-be-built building. This resulted into eleven different Scenarios. It seems obvious that the design space for thermal retrofit by far outreaches these scenarios. As such this should be understood as a starting point. Uncertainties regarding input data persisted in this case study, and presumably will be immanent for other, future case studies.

To widen the knowledge, the present methodology should be extended regarding number of case study buildings, major assumptions for envelope, occupancy, and building systems characteristics. Moreover, a more detailed set of results could presumably be derived with simulation tools that allow hour-based assessments. Furthermore, a change of the system boundary in the life-cycle-assessment regarding the utilized time frame might offer other insights, if one considers that the average lifespan of a building today does not exceed 30 years. For example, comparisons between a use phase of 10, 20 or 100 years could be conducted, which presumably might end up in slightly different conclusions.

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6 INDEX

6.1 List of Abbreviations

AP ..... acidification potential
cm ..... centimeter
CO_2 ..... carbon dioxide
EPS ..... expanded polystyrene
GWP ..... global warming potential
HWB ..... heating demand
HWB_{SK} ..... heating demand for site climate
IBO ..... Austrian Institute for Building and Ecology
K ..... kelvin
kg ..... kilogram
$kg.m^{-2}$ ..... kilogram per square meter
kWh ..... kilowatt hours
$kWh.m^{-2}$ ..... kilowatt hours per square meter
$kWh.m^{-2}.a^{-1}$ ..... kilowatt hours per spare meter and year
LCA ..... life cycle assessment
m ..... meter
m^2 ..... square meter
MJ ..... megajoule
$MJ.m^{-2}$ ..... megajoule per square meter
OI3 ..... eco-index
OSB ..... oriented strand board
PEI n.e. ..... non-renewable energy resource requirement
SO_2 ..... sulfur dioxide
W ..... watt
$W.m^{-2}.K^{-1}$ ..... watt per square meter kelvin
XPS ..... extruded polystyrene

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6.4 List of Equations

$$\Delta OI3 = 1/3 * [1/10 * (PEI\ n.e.) + 1/2 * (GWP) + 100/0{,}25 * (AP)] \quad (1)$$

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8 APPENDIX

A. Building Components

HOUSE A

Exterior wall 01:		U-value: 2.387 [W.m^{-2}.K^{-1}]
1.50 cm	Exterior plaster	λ= 1.400 [W.m^{-1}.K^{-1}]
50.00 cm	Nature brick masonry	λ= 2.300 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Exterior wall 02 (to garage):		U-value: 1.965 [W.m^{-2}.K^{-1}]
1.50 cm	Exterior plaster	λ= 1.400 [W.m^{-1}.K^{-1}]
50.00 cm	Nature brick masonry	λ= 2.300 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to unheated attic:		U-value: 0.544 [W.m^{-2}.K^{-1}]
12.00 cm	Bricks	λ= 0.590 [W.m^{-1}.K^{-1}]
1.00 cm	Straw clay	λ= 0.600 [W.m^{-1}.K^{-1}]
18.00 cm	Timbered ceiling	λ= 0.130 [W.m^{-1}.K^{-1}]
1.00 cm	Reed as plaster base	λ= 0.800 [W.m^{-1}.K^{-1}]
1.5 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to ground 01:		U-value: 1.481 [W.m^{-2}.K^{-1}]
20.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	Concrete	λ= 0.980 [W.m^{-1}.K^{-1}]
2.00 cm	Tiles	λ= 1.300 [W.m^{-1}.K^{-1}]

Ceiling to ground 02:		U-value: 1.391 [W.m^{-2}.K^{-1}]
20.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	Concrete	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Linoleum	λ= 0.170 [W.m^{-1}.K^{-1}]

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Ceiling to ground 03: U-value: 1.274 [$W.m^{-2}.K^{-1}$]

20.00 cm	Gravel	λ= 0.700 [$W.m^{-1}.K^{-1}$]
20.00 cm	Concrete	λ= 0.980 [$W.m^{-1}.K^{-1}$]
1.00 cm	Carpet	λ= 0.080 [$W.m^{-1}.K^{-1}$]

Ceiling to ground 04: U-value: 1.357 [$W.m^{-2}.K^{-1}$]

20.00 cm	Gravel	λ= 0.700 [$W.m^{-1}.K^{-1}$]
20.00 cm	Concrete	λ= 0.980 [$W.m^{-1}.K^{-1}$]
1.00 cm	Laminate	λ= 0.130 [$W.m^{-1}.K^{-1}$]

Window 01 (big): U-value: 2.71 [$W.m^{-2}.K^{-1}$]

Double Glazing (6-8-6)
JOSKO Plastic frame (without insulation)

Window 02 (middle): U-value: 2.68 [$W.m^{-2}.K^{-1}$]

Double Glazing (6-8-6)
JOSKO Plastic frame (without insulation)

Window 03 (small): U-value: 2.71 [$W.m^{-2}.K^{-1}$]

Double Glazing (6-8-6)
JOSKO Plastic frame (without insulation)

Entrance door (including glazed parts): U-value: 1.62 [$W.m^{-2}.K^{-1}$]

Double Glazing (6-8-6)
JOSKO Plastic frame (without insulation)

Interior wall 01: U-value: 0.923 [$W.m^{-2}.K^{-1}$]

1.50 cm	Interior plaster	λ= 0.700 [$W.m^{-1}.K^{-1}$]
50.00 cm	Brick masonry	λ= 0.640 [$W.m^{-1}.K^{-1}$]
1.50 cm	Interior plaster	λ= 0.700 [$W.m^{-1}.K^{-1}$]

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Interior wall 02:		U-value: 1.222 [W.m^{-2}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]
33.00 cm	Brick masonry	λ= 0.640 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Interior wall 03:		U-value: 1.866 [W.m^{-2}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]
15.00 cm	Brick masonry	λ= 0.640 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

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SCENARIO A.1.1

Window 01 (big): U-value: 0.97 [$W.m^{-2}.K^{-1}$]

Triple heat protection glass, argon

JOSKO Wood-aluminium frame TITAN 101 – spruce wood

Window 02 (middle): U-value: 0.98 [$W.m^{-2}.K^{-1}$]

Triple heat protection glass, argon

JOSKO Wood-aluminium frame TITAN 101 – spruce wood

Window 03 (small): U-value: 1.05 [$W.m^{-2}.K^{-1}$]

Triple heat protection glass, argon

JOSKO Wood-aluminium frame TITAN 101 – spruce wood

All other building components are equal to those of House A.

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SCENARIO A.1.2

Window 01 (big): U-value: 0.80 [$W.m^{-2}.K^{-1}$]

Triple glazing, MGTherm Öko Star 0,5 (4-18-4-18-4 Ar)
JOSKO Wood frame RUBIN 90 – spruce wood

Window 02 (middle): U-value: 0.82 [$W.m^{-2}.K^{-1}$]

Triple glazing, MGTherm Öko Star 0,5 (4-18-4-18-4 Ar)
JOSKO Wood frame RUBIN 90 – spruce wood

Window 03 (small): U-value: 0.92 [$W.m^{-2}.K^{-1}$]

Triple glazing, MGTherm Öko Star 0,5 (4-18-4-18-4 Ar)
JOSKO Wood frame RUBIN 90 – spruce wood

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SCENARIO A.2.1

Exterior wall 01: U-value: 0.185 [$W.m^{-2}.K^{-1}$]

1.50 cm	Heat insulation plaster	λ= 0.090 [$W.m^{-1}.K^{-1}$]
15.00 cm	EPS F PLUS (Austrotherm)	λ= 0.031 [$W.m^{-1}.K^{-1}$]
50.00 cm	Nature brick masonry	λ= 2.300 [$W.m^{-1}.K^{-1}$]
1.50 cm	Interior plaster	λ= 0.700 [$W.m^{-1}.K^{-1}$]

Exterior wall 02 (to garage): U-value: 1.965 [$W.m^{-2}.K^{-1}$]

1.50 cm	Heat insulation plaster	λ= 0.090 [$W.m^{-1}.K^{-1}$]
15.00 cm	EPS F PLUS (Austrotherm)	λ= 0.031 [$W.m^{-1}.K^{-1}$]
50.00 cm	Nature brick masonry	λ= 2.300 [$W.m^{-1}.K^{-1}$]
1.50 cm	Interior plaster	λ= 0.700 [$W.m^{-1}.K^{-1}$]

Ceiling to unheated attic: U-value: 0.215 [$W.m^{-2}.K^{-1}$]

1.50 cm	Oriented strand board (OSB)	λ= 0.130 [$W.m^{-1}.K^{-1}$]
10.00 cm	XPS-R (rough surface)	λ= 0.037 [$W.m^{-1}.K^{-1}$]
12.00 cm	Bricks	λ= 0.590 [$W.m^{-1}.K^{-1}$]
1.00 cm	Straw clay	λ= 0.600 [$W.m^{-1}.K^{-1}$]
18.00 cm	Timbered ceiling	λ= 0.130 [$W.m^{-1}.K^{-1}$]
1.00 cm	Reed as plaster base	λ= 0.800 [$W.m^{-1}.K^{-1}$]
1.5 cm	Interior plaster	λ= 0.700 [$W.m^{-1}.K^{-1}$]

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SCENARIO A.2.2

Exterior wall 01:		U-value: 0.256 [W.m^{-2}.K^{-1}]
1.50 cm	Heat insulation plaster	λ= 0.090 [W.m^{-1}.K^{-1}]
15.00 cm	Wood fiber board (R=150)	λ= 0.045 [W.m^{-1}.K^{-1}]
50.00 cm	Nature brick masonry	λ= 2.300 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Exterior wall 02 (to garage):		U-value: 0.250 [W.m^{-2}.K^{-1}]
1.50 cm	Heat insulation plaster	λ= 0.090 [W.m^{-1}.K^{-1}]
15.00 cm	Wood fiber board (R=150)	λ= 0.045 [W.m^{-1}.K^{-1}]
50.00 cm	Nature brick masonry	λ= 2.300 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to unheated attic:		U-value: 0.239 [W.m^{-2}.K^{-1}]
1.50 cm	Oriented strand board (OSB)	λ= 0.130 [W.m^{-1}.K^{-1}]
10.00 cm	Wood fiber board (R=150)	λ= 0.045 [W.m^{-1}.K^{-1}]
12.00 cm	Bricks	λ= 0.590 [W.m^{-1}.K^{-1}]
1.00 cm	Straw clay	λ= 0.600 [W.m^{-1}.K^{-1}]
18.00 cm	Timbered ceiling	λ= 0.130 [W.m^{-1}.K^{-1}]
1.00 cm	Reed as plaster base	λ= 0.800 [W.m^{-1}.K^{-1}]
1.5 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

All other building components are equal to those of House A.

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SCENARIO A.3

Exterior wall 01: U-value: 0.142 [W.m^{-2}.K^{-1}]

1.50 cm	Heat insulation plaster	λ= 0.090 [W.m^{-1}.K^{-1}]
20.00 cm	EPS F PLUS (Austrotherm)	λ= 0.031 [W.m^{-1}.K^{-1}]
50.00 cm	Nature brick masonry	λ= 2.300 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Exterior wall 02 (to garage): U-value: 0.141 [W.m^{-2}.K^{-1}]

1.50 cm	Heat insulation plaster	λ= 0.090 [W.m^{-1}.K^{-1}]
20.00 cm	EPS F PLUS (Austrotherm)	λ= 0.031 [W.m^{-1}.K^{-1}]
50.00 cm	Nature brick masonry	λ= 2.300 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to unheated attic: U-value: 0.136 [W.m^{-2}.K^{-1}]

1.50 cm	Oriented strand board (OSB)	λ= 0.130 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-R (rough surface, d<130 mm)	λ= 0.037 [W.m^{-1}.K^{-1}]
12.00 cm	Bricks	λ= 0.590 [W.m^{-1}.K^{-1}]
1.00 cm	Straw clay	λ= 0.600 [W.m^{-1}.K^{-1}]
18.00 cm	Timbered ceiling	λ= 0.130 [W.m^{-1}.K^{-1}]
1.00 cm	Reed as plaster base	λ= 0.800 [W.m^{-1}.K^{-1}]
1.5 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to ground 01: U-value: 0.132 [W.m^{-2}.K^{-1}]

50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m³)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
2.00 cm	Tiles	λ= 1.300 [W.m^{-1}.K^{-1}]

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Ceiling to ground 02: U-value: 0.131 [W.m^{-2}.K^{-1}]

50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m³)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Linoleum	λ= 0.170 [W.m^{-1}.K^{-1}]

Ceiling to ground 03: U-value: 0.130 [W.m^{-2}.K^{-1}]

50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m³)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Carpet	λ= 0.080 [W.m^{-1}.K^{-1}]

Ceiling to ground 04: U-value: 0.131 [W.m^{-2}.K^{-1}]

50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m³)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Laminate	λ= 0.130 [W.m^{-1}.K^{-1}]

Window 01 (big): U-value: 0.98 [W.m^{-2}.K^{-1}]

Triple heat protection glass, argon

JOSKO Wood frame RUBIN 90 – spruce wood

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Window 02 (middle): U-value: 0.82 [W.m^{-2}.K^{-1}]

Triple glazing, MGTherm Öko Star 0,5 (4-18-4-18-4 Ar)

JOSKO Wood frame RUBIN 90 – spruce wood

Window 03 (small): U-value: 0.92 [W.m^{-2}.K^{-1}]

Triple glazing, MGTherm Öko Star 0,5 (4-18-4-18-4 Ar)

JOSKO Wood frame RUBIN 90 – spruce wood

Entrance door (including glazed parts): U-value: 1.03 [W.m^{-2}.K^{-1}]

Triple heat protection glass, argon

JOSKO Wood frame RUBIN 90 – spruce wood

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HOUSE B

Exterior wall 01: U-value: 0.357 [W.m^{-2}.K^{-1}]

1.50 cm	Exterior plaster	λ= 1.400 [W.m^{-1}.K^{-1}]
20.00 cm	EPS F (Austrotherm)	λ= 0.040 [W.m^{-1}.K^{-1}]
30.00 cm	Bricks (lightweight concrete)	λ= 0.500 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.130 [W.m^{-1}.K^{-1}]

Ceiling o unheated attic: U-value: 0.920 [W.m^{-2}.K^{-1}]

8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.40 cm	Bitumen vapour barrier	λ= 0.170 [W.m^{-1}.K^{-1}]
18.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling o unheated basement 01: U-value: 0.821 [W.m^{-2}.K^{-1}]

1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]
18.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
2.00 cm	Tiles	λ= 1.300 [W.m^{-1}.K^{-1}]

Ceiling o unheated basement 02: U-value: 0.792 [W.m^{-2}.K^{-1}]

1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]
18.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Linoleum	λ= 0.170 [W.m^{-1}.K^{-1}]

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Ceiling o unheated basement 03: U-value: 0.753 [W.m^{-2}.K^{-1}]

1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]
18.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Carpet	λ= 0.080 [W.m^{-1}.K^{-1}]

Ceiling o unheated basement 04: U-value: 0.781 [W.m^{-2}.K^{-1}]

1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]
18.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Laminate	λ= 0.130 [W.m^{-1}.K^{-1}]

Window 01 (big): U-value: 2.71 [W.m^{-2}.K^{-1}]

Double Glazing (6-8-6)
JOSKO Plastic frame (without insulation)

Window 02 (small): U-value: 2.12 [W.m^{-2}.K^{-1}]

Double Glazing (6-8-6)
JOSKO Plastic frame (without insulation)

Entrance door (including glazed parts): U-value: 1.86 [W.m^{-2}.K^{-1}]

Double Glazing (6-8-6)
JOSKO Plastic frame (without insulation)

Interior wall 01: U-value: 1.742 [W.m^{-2}.K^{-1}]

1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]
25.00 cm	Bricks (hollow concrete blocks)	λ= 0.920 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

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Interior wall 02:		U-value: 2.433 [$W.m^{-2}.K^{-1}$]
1.50 cm	Interior plaster	λ= 0.700 [$W.m^{-1}.K^{-1}$]
10.00 cm	Bricks (hollow concrete blocks)	λ= 0.920 [$W.m^{-1}.K^{-1}$]
1.50 cm	Interior plaster	λ= 0.700 [$W.m^{-1}.K^{-1}$]

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SCENARIO B.1.1

Window 01 (big): U-value: 0.96 [$W.m^{-2}.K^{-1}$]

Triple heat protection glass, argon

JOSKO Wood-aluminium frame TITAN 101 – spruce wood

Window 02 (small): U-value: 1.14 [$W.m^{-2}.K^{-1}$]

Triple heat protection glass, argon

JOSKO Wood-aluminium frame TITAN 101 – spruce wood

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SCENARIO B.1.2

Window 01 (big): U-value: 0.80 [$W.m^{-2}.K^{-1}$]

Triple glazing, MGTherm Öko Star 0,5 (4-18-4-18-4 Ar)
JOSKO Wood frame RUBIN 90 – spruce wood

Window 02 (small): U-value: 1.07 [$W.m^{-2}.K^{-1}$]

Triple glazing, MGTherm Öko Star 0,5 (4-18-4-18-4 Ar)
JOSKO Wood frame RUBIN 90 – spruce wood

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SCENARIO B.2.1

Exterior wall 01:		U-value: 0.173 [W.m^{-2}.K^{-1}]
1.50 cm	Heat insulation plaster	λ= 0.090 [W.m^{-1}.K^{-1}]
15.00 cm	EPS F PLUS (Austrotherm)	λ= 0.031 [W.m^{-1}.K^{-1}]
30.00 cm	Bricks (lightweight concrete)	λ= 0.500 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to unheated attic:		U-value: 0.318 [W.m^{-2}.K^{-1}]
1.50 cm	Oriented strand board (OSB)	λ= 0.130 [W.m^{-1}.K^{-1}]
10.00 cm	XPS-R (rough surface)	λ= 0.037 [W.m^{-1}.K^{-1}]
0.40 cm	Bitumen vapour barrier	λ= 0.170 [W.m^{-1}.K^{-1}]
18.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
1.5 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

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SCENARIO B.2.2

Exterior wall 01:		U-value: 0.233 [W.m^{-2}.K^{-1}]
1.50 cm	Heat insulation plaster	λ= 0.090 [W.m^{-1}.K^{-1}]
15.00 cm	Wood fiber board	λ= 0.045 [W.m^{-1}.K^{-1}]
30.00 cm	Bricks (lightweight concrete)	λ= 0.500 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to unheated attic:		U-value: 0.376 [W.m^{-2}.K^{-1}]
1.50 cm	Oriented strand board (OSB)	λ= 0.130 [W.m^{-1}.K^{-1}]
10.00 cm	Wood fiber board	λ= 0.045 [W.m^{-1}.K^{-1}]
0.40 cm	Bitumen vapor barrier	λ= 0.170 [W.m^{-1}.K^{-1}]
18.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
1.5 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

All other building components are equal to those of House B.

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SCENARIO B.3

Exterior wall 01:		U-value: 0.135 [W.m^{-2}.K^{-1}]
1.50 cm	Heat insulation plaster	λ= 0.090 [W.m^{-1}.K^{-1}]
20.00 cm	EPS F PLUS (Austrotherm)	λ= 0.031 [W.m^{-1}.K^{-1}]
30.00 cm	Bricks (lightweight concrete)	λ= 0.500 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to unheated attic:		U-value: 0.171 [W.m^{-2}.K^{-1}]
1.50 cm	Oriented strand board (OSB)	λ= 0.130 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-R (rough surface)	λ= 0.037 [W.m^{-1}.K^{-1}]
0.40 cm	Bitumen vapour barrier	λ= 0.170 [W.m^{-1}.K^{-1}]
18.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
1.5 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to ground 01:		U-value: 0.132 [W.m^{-2}.K^{-1}]
50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m^3)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
2.00 cm	Tiles	λ= 1.300 [W.m^{-1}.K^{-1}]

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Ceiling to ground 02: U-value: 0.131 [W.m^{-2}.K^{-1}]

50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m³)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Linoleum	λ= 0.170 [W.m^{-1}.K^{-1}]

Ceiling to ground 03: U-value: 0.130 [W.m^{-2}.K^{-1}]

50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m³)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Carpet	λ= 0.080 [W.m^{-1}.K^{-1}]

Ceiling to ground 04: U-value: 0.131 [W.m^{-2}.K^{-1}]

50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m³)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Laminate	λ= 0.130 [W.m^{-1}.K^{-1}]

Window 01 (big): U-value: 0.98 [W.m^{-2}.K^{-1}]

Triple heat protection glass, argon

JOSKO Wood frame RUBIN 90 – spruce wood

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Window 02 (small): U-value: 1.17 [$W.m^{-2}.K^{-1}$]

Triple heat protection glass, argon

JOSKO Wood frame RUBIN 90 – spruce wood

Entrance door (including glazed parts): U-value: 0.99 [$W.m^{-2}.K^{-1}$]

Triple heat protection glass, argon

JOSKO Wood frame RUBIN 90 – spruce wood

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HOUSE C / SCENARIO C

Exterior wall 01:		U-value: 0.095 [W.m^{-2}.K^{-1}]
1.50 cm	Heat insulation plaster	λ= 1.400 [W.m^{-1}.K^{-1}]
30.00 cm	EPS F PLUS (Austrotherm)	λ= 0.031 [W.m^{-1}.K^{-1}]
30.00 cm	Bricks (lightweight concrete)	λ= 0.500 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to unheated attic:		U-value: 0.117 [W.m^{-2}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-R (rough surface)	λ= 0.037 [W.m^{-1}.K^{-1}]
0.40 cm	Bitumen vapour barrier	λ= 0.170 [W.m^{-1}.K^{-1}]
18.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
1.5 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Ceiling to ground 01:		U-value: 0.132 [W.m^{-2}.K^{-1}]
50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m^3)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
2.00 cm	Tiles	λ= 1.300 [W.m^{-1}.K^{-1}]

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Ceiling to ground 02: U-value: 0.131 [W.m^{-2}.K^{-1}]

50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m³)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Linoleum	λ= 0.170 [W.m^{-1}.K^{-1}]

Ceiling to ground 03: U-value: 0.130 [W.m^{-2}.K^{-1}]

50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m³)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Carpet	λ= 0.080 [W.m^{-1}.K^{-1}]

Ceiling to ground 04: U-value: 0.131 [W.m^{-2}.K^{-1}]

50.00 cm	Gravel	λ= 0.700 [W.m^{-1}.K^{-1}]
20.00 cm	XPS-G 50 > 180 mm (38 kg/m³)	λ= 0.042 [W.m^{-1}.K^{-1}]
20.00 cm	Reinforced concrete	λ= 2.300 [W.m^{-1}.K^{-1}]
0.10 cm	Sealing	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	EPS granulate levelling compound	λ= 0.075 [W.m^{-1}.K^{-1}]
3.00 cm	Footfall sound insulation	λ= 0.044 [W.m^{-1}.K^{-1}]
0.10 cm	PE-foil	λ= 0.230 [W.m^{-1}.K^{-1}]
8.00 cm	Screed (cement screed)	λ= 0.980 [W.m^{-1}.K^{-1}]
1.00 cm	Laminate	λ= 0.130 [W.m^{-1}.K^{-1}]

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Interior wall 01: U-value: 1.742 [W.m^{-2}.K^{-1}]

1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]
25.00 cm	Bricks (hollow concrete blocks)	λ= 0.920 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Interior wall 02: U-value: 2.433 [W.m^{-2}.K^{-1}]

1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]
10.00 cm	Bricks (hollow concrete blocks)	λ= 0.920 [W.m^{-1}.K^{-1}]
1.50 cm	Interior plaster	λ= 0.700 [W.m^{-1}.K^{-1}]

Roof: U-value: 0.795 [W.m^{-2}.K^{-1}]

2.00 cm	Roof tile
4.00 cm	Lathing (wood – spruce)
	among them: air
0.10 cm	Polymeric bitumen sealing sheet
4.00 cm	Counterbattening
	among them: air
4.00 cm	Wooden formwork
0.10 cm	Aluminium vapour barrier
24.00 cm	Rafters
	among them: air

Window 01 (big): U-value: 0.98 [W.m^{-2}.K^{-1}]

Triple heat protection glass, argon

JOSKO Wood frame RUBIN 90 – spruce wood

Window 02 (small): U-value: 1.17 [W.m^{-2}.K^{-1}]

Triple heat protection glass, argon

JOSKO Wood frame RUBIN 90 – spruce wood

Entrance door (including glazed parts): U-value: 0.99 [W.m^{-2}.K^{-1}]

Triple heat protection glass, argon

JOSKO Wood frame RUBIN 90 – spruce wood

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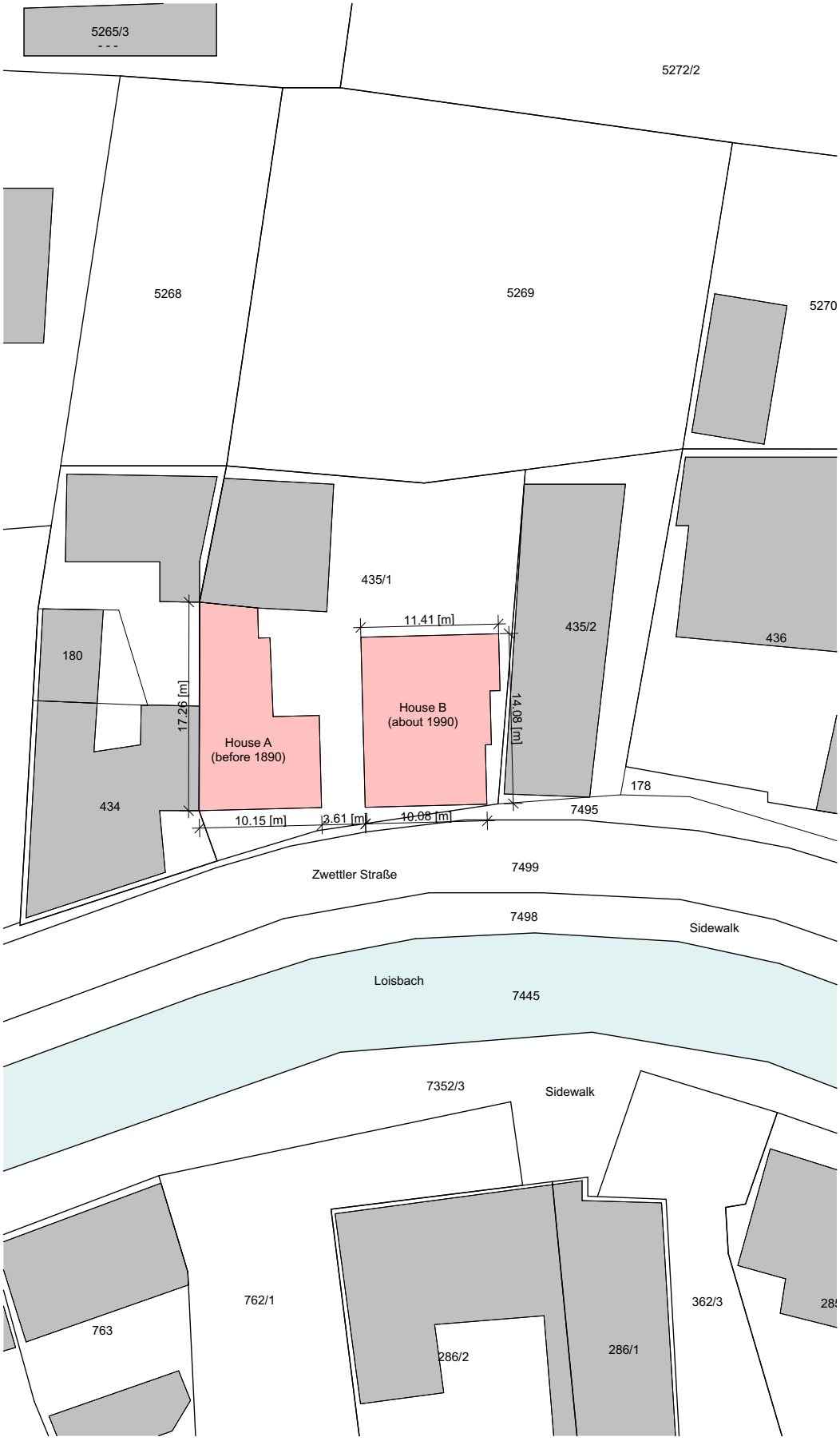
B. Plans

Location of Houses
M=1:500



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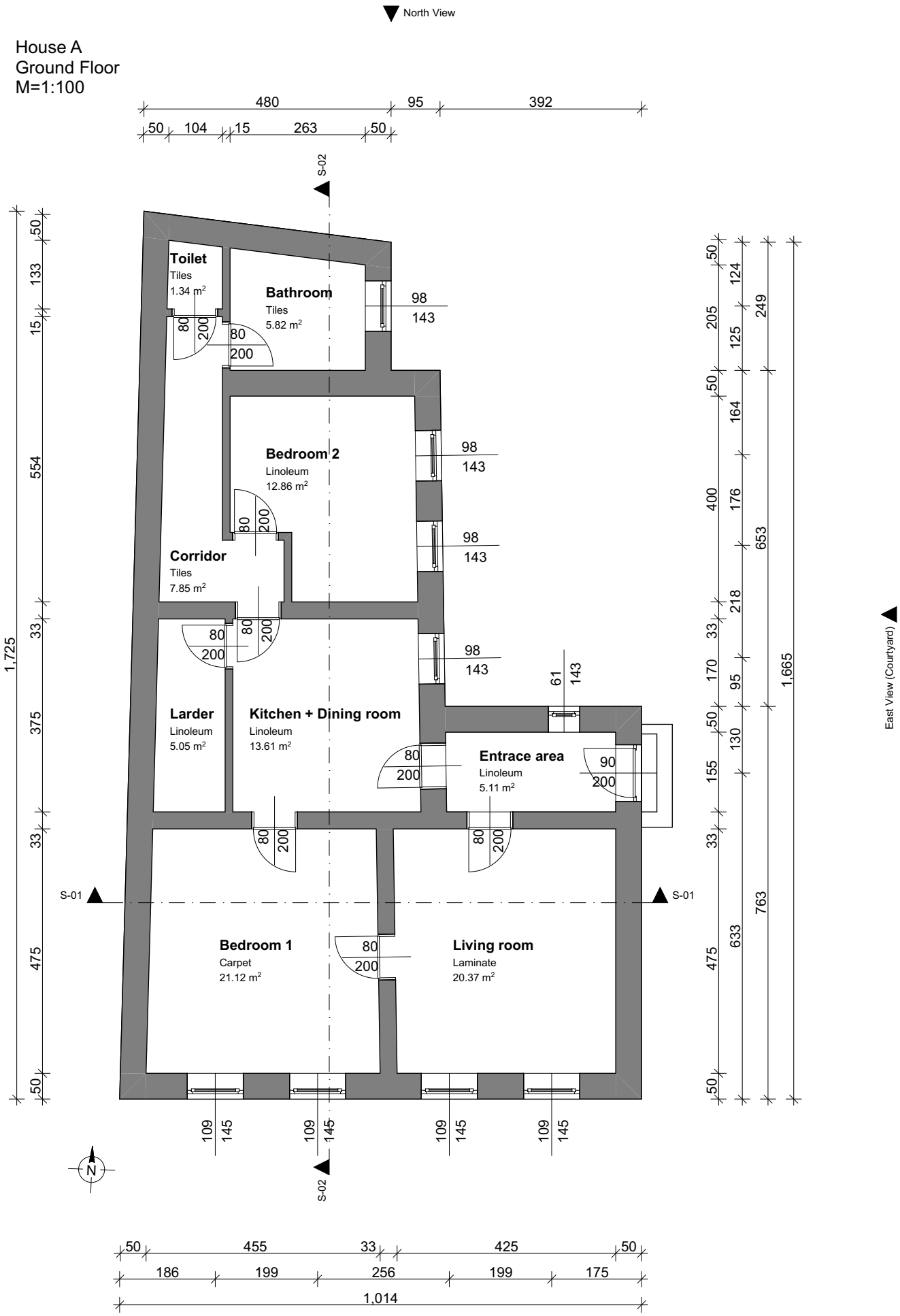
House A
Ground Floor
M=1:100



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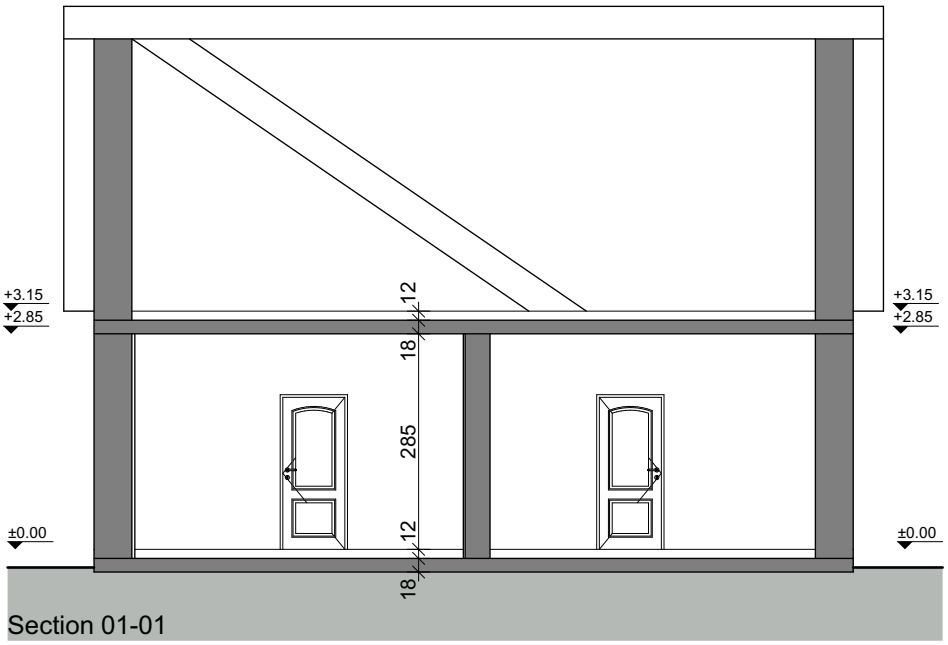
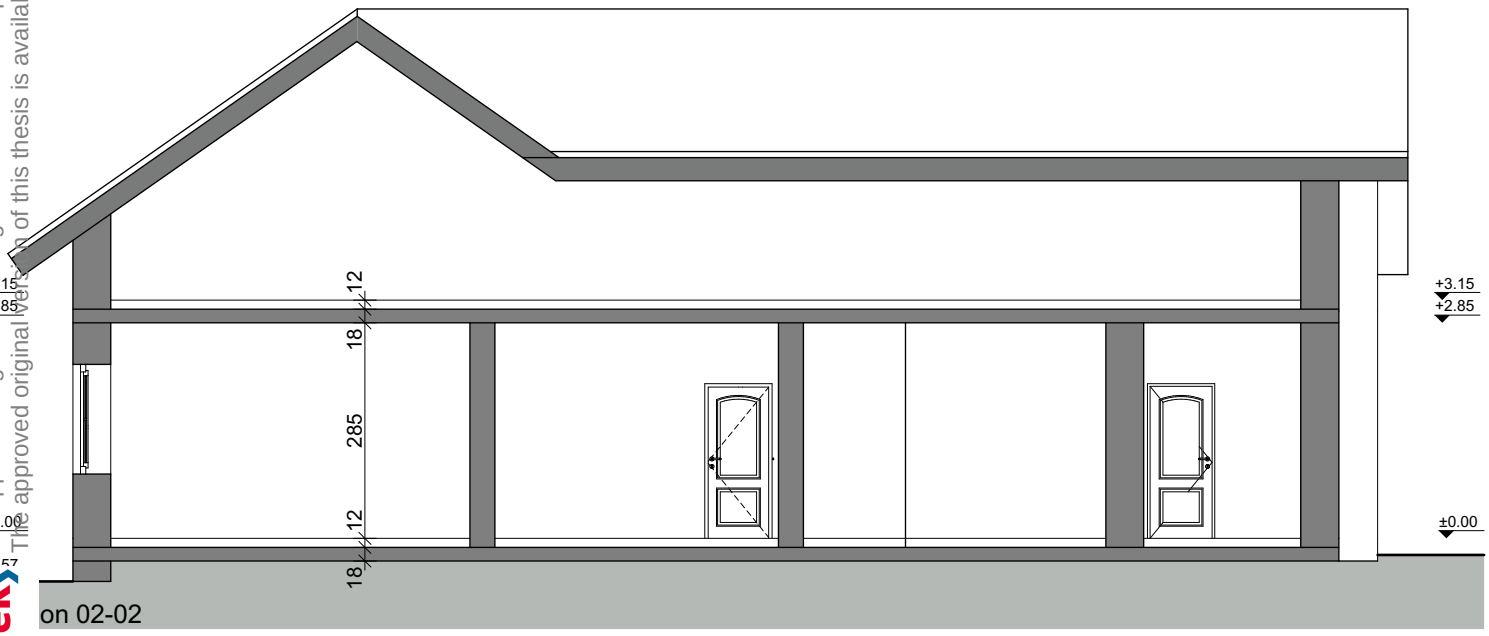
House A
Sections
M=1:100



Section 01-01



on 02-02

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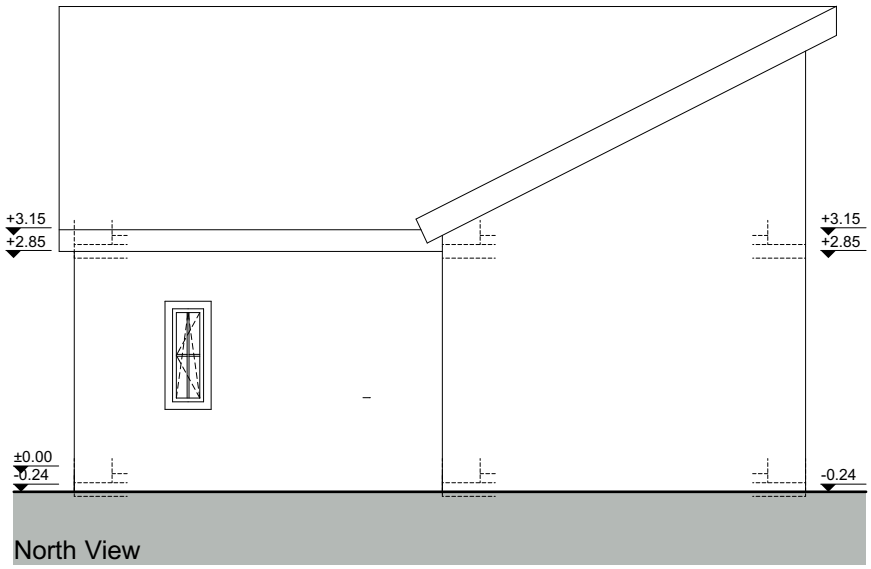
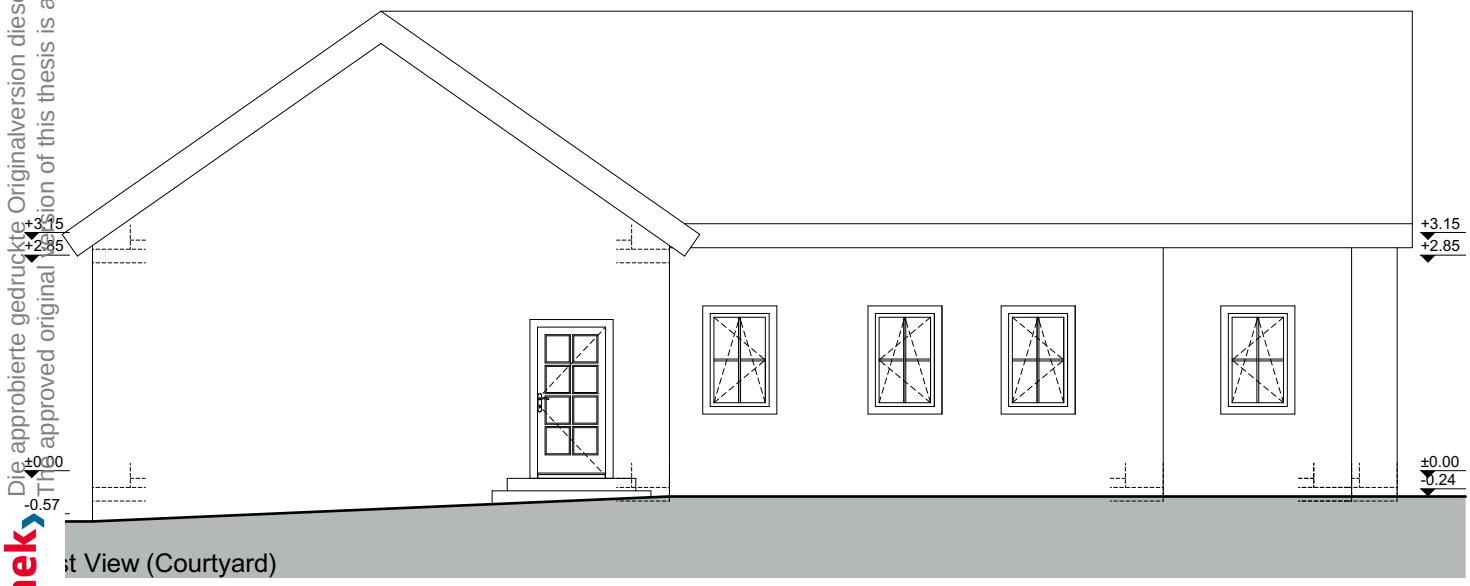
House A
Views
M=1:100





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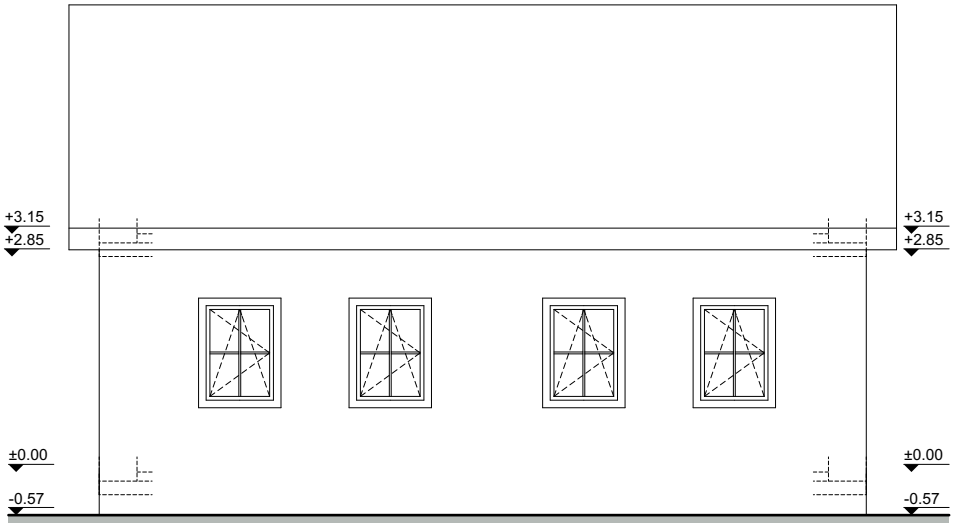
House A
Views
M=1:100



South View (Street)

est View (Neighbour)

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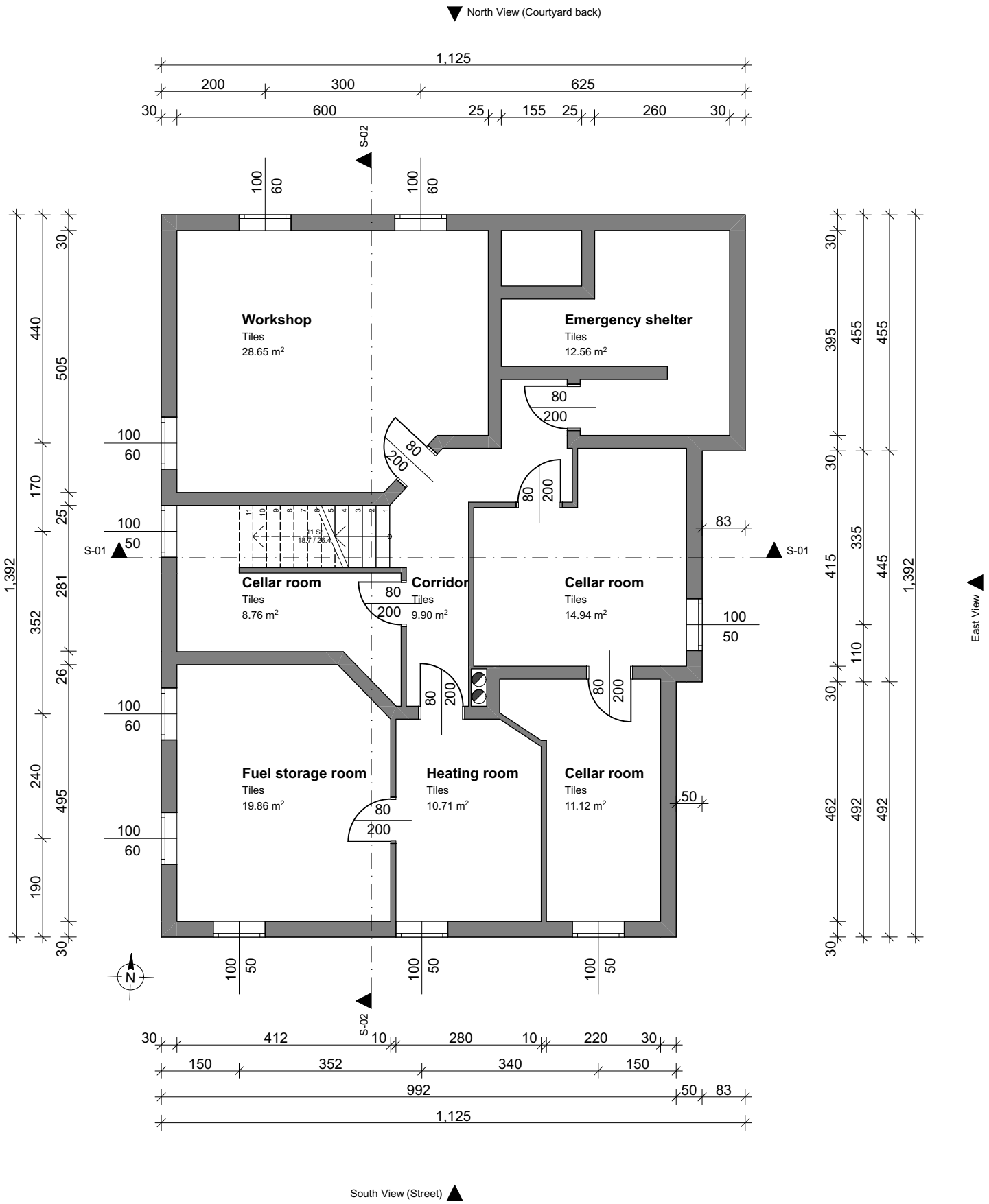
House B
Basement
M=1:100



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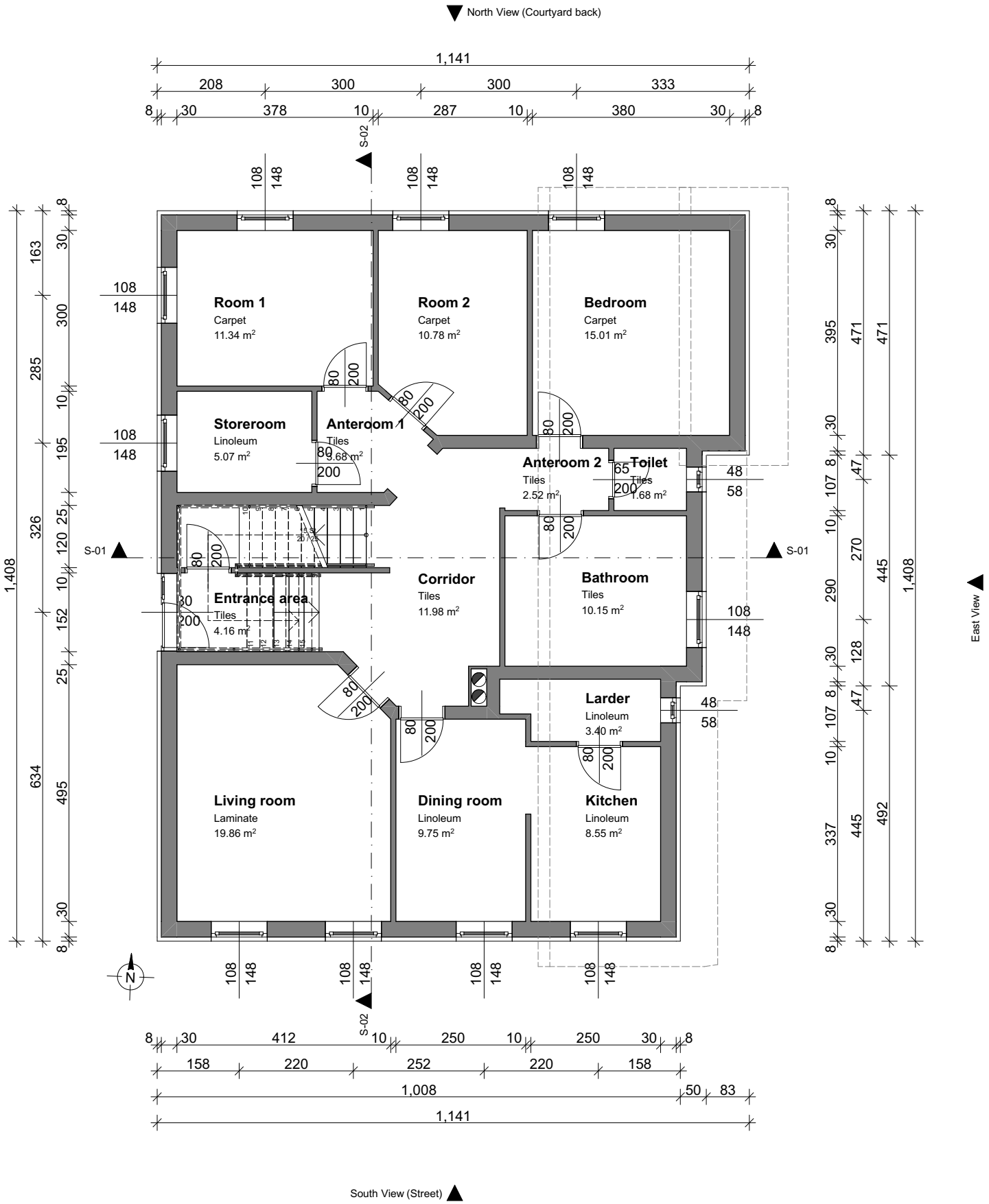
House B
Groundfloor
M=1:100



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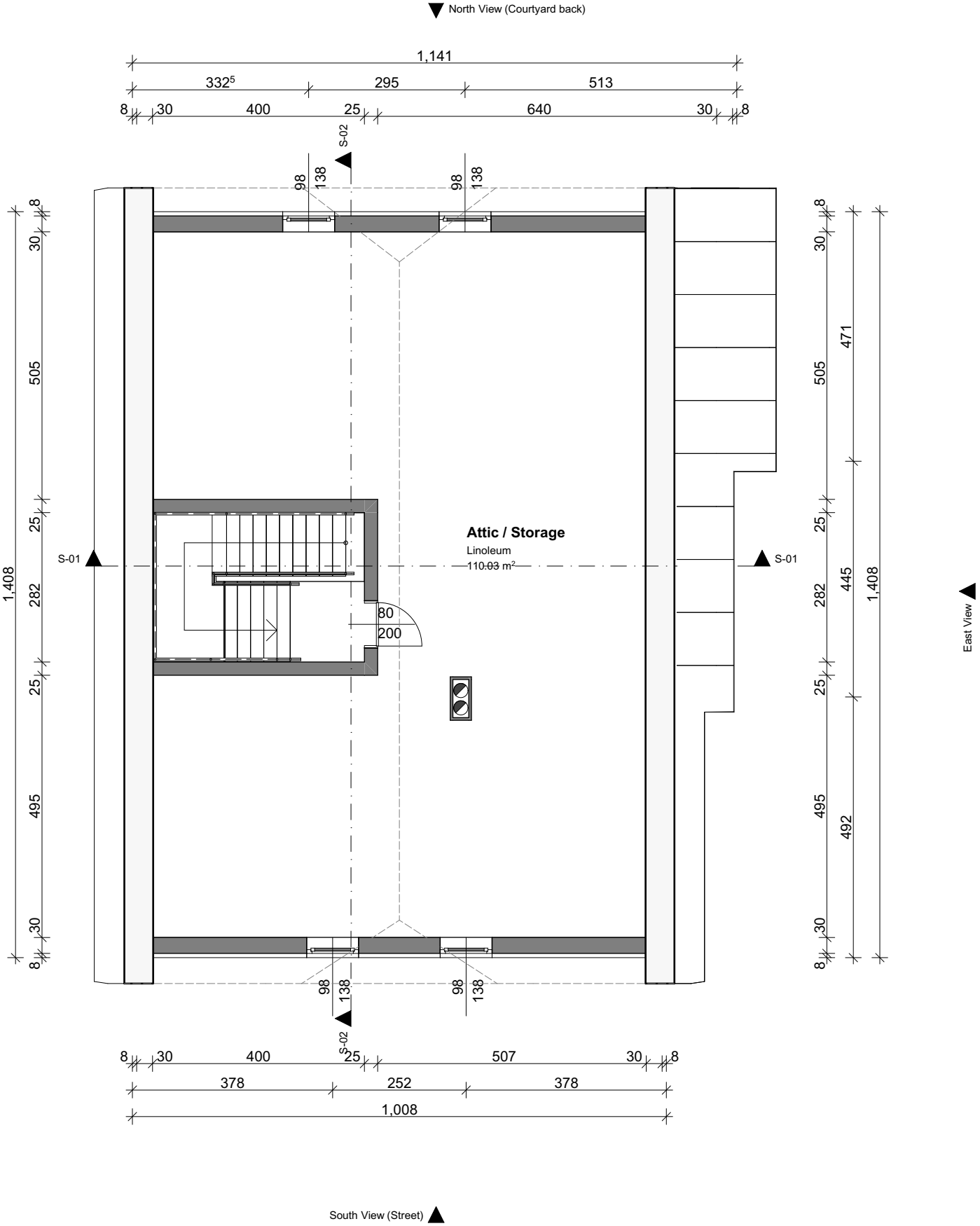
House B
Attic
M=1:100



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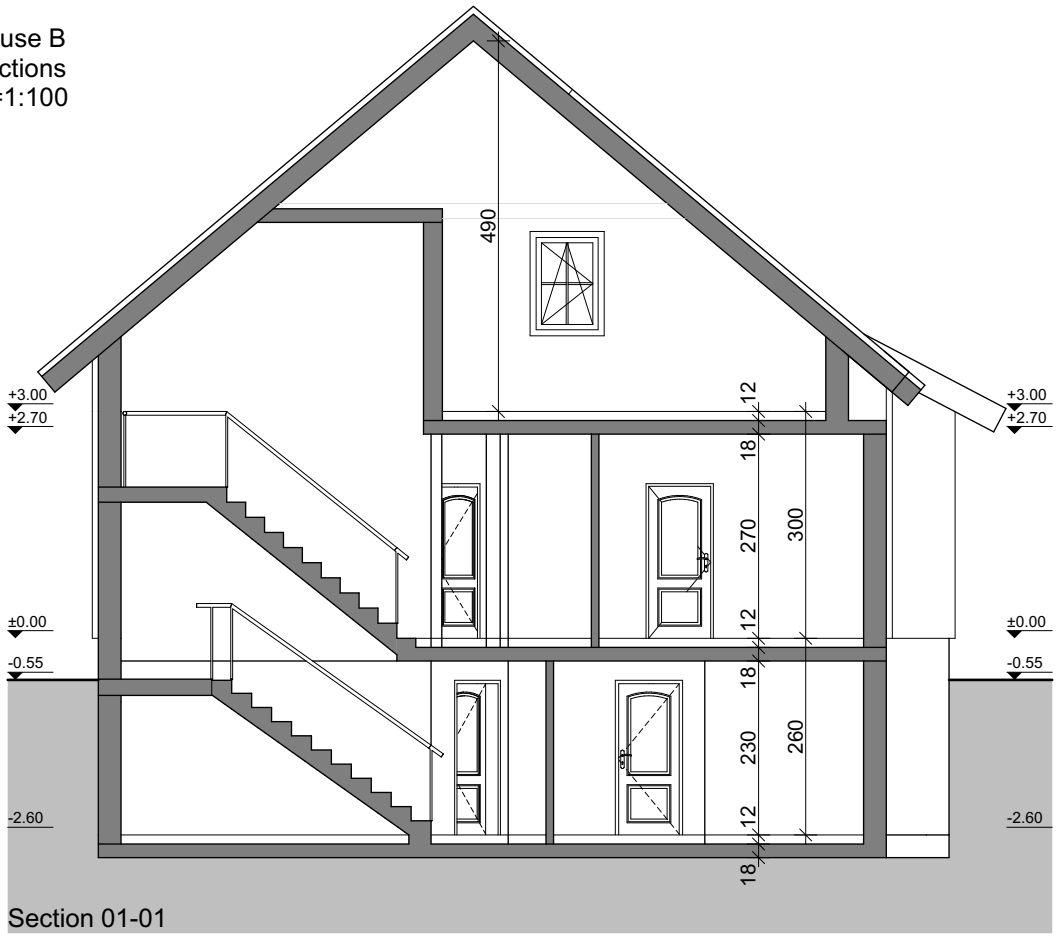
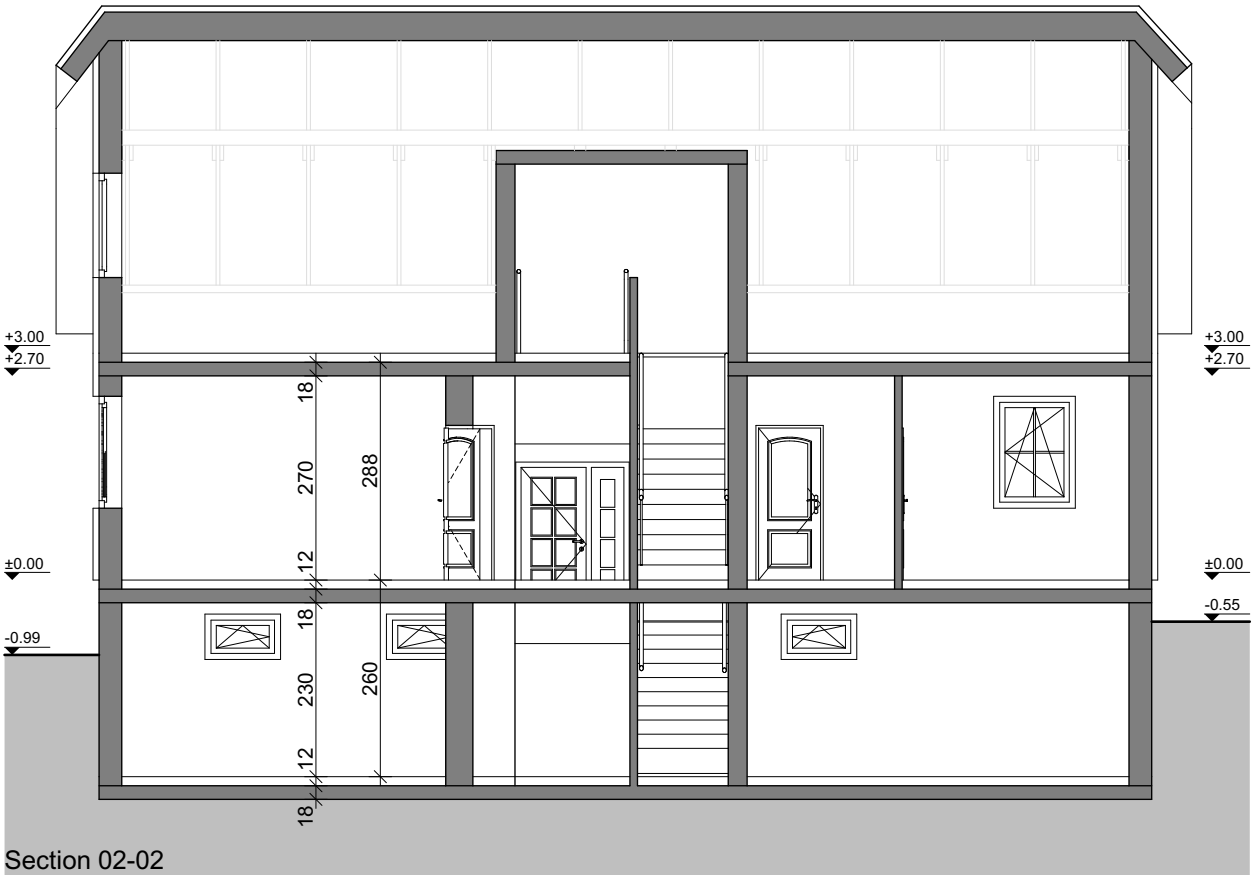
House B
Sections
M=1:100



Section 01-01



Section 02-02

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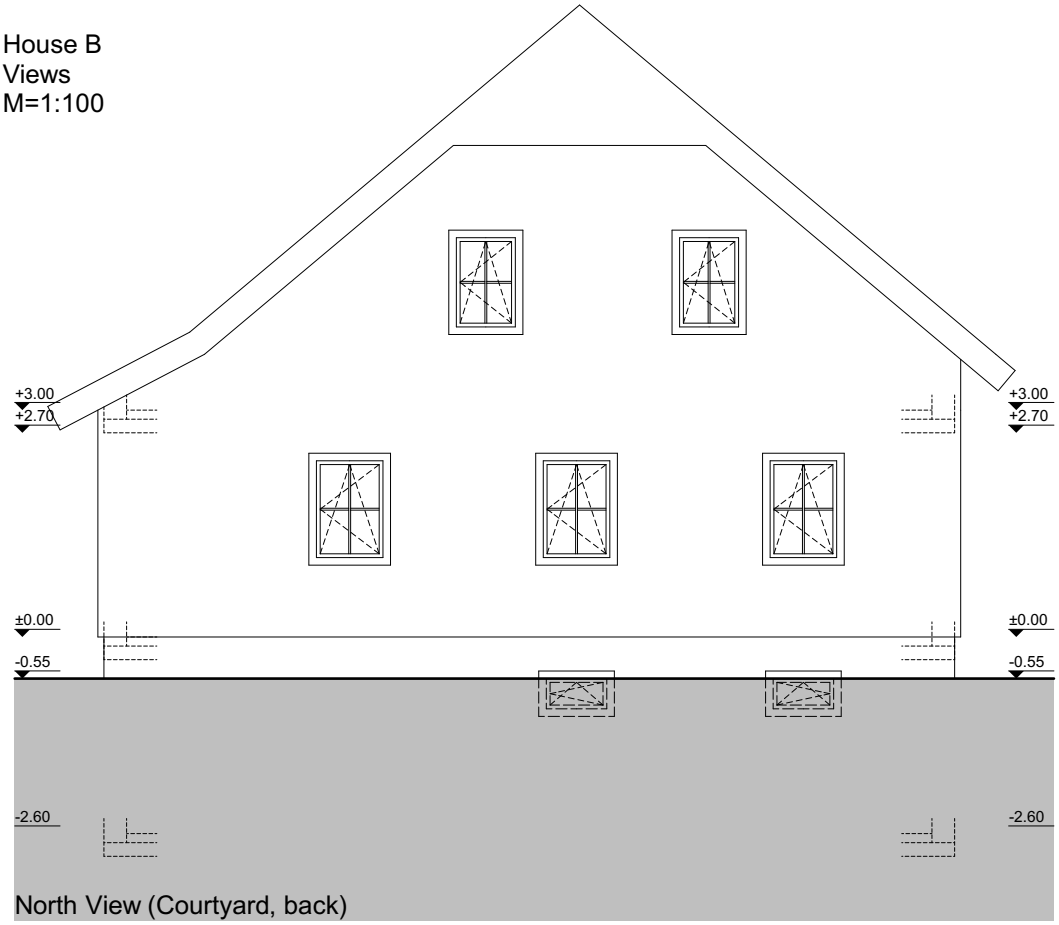
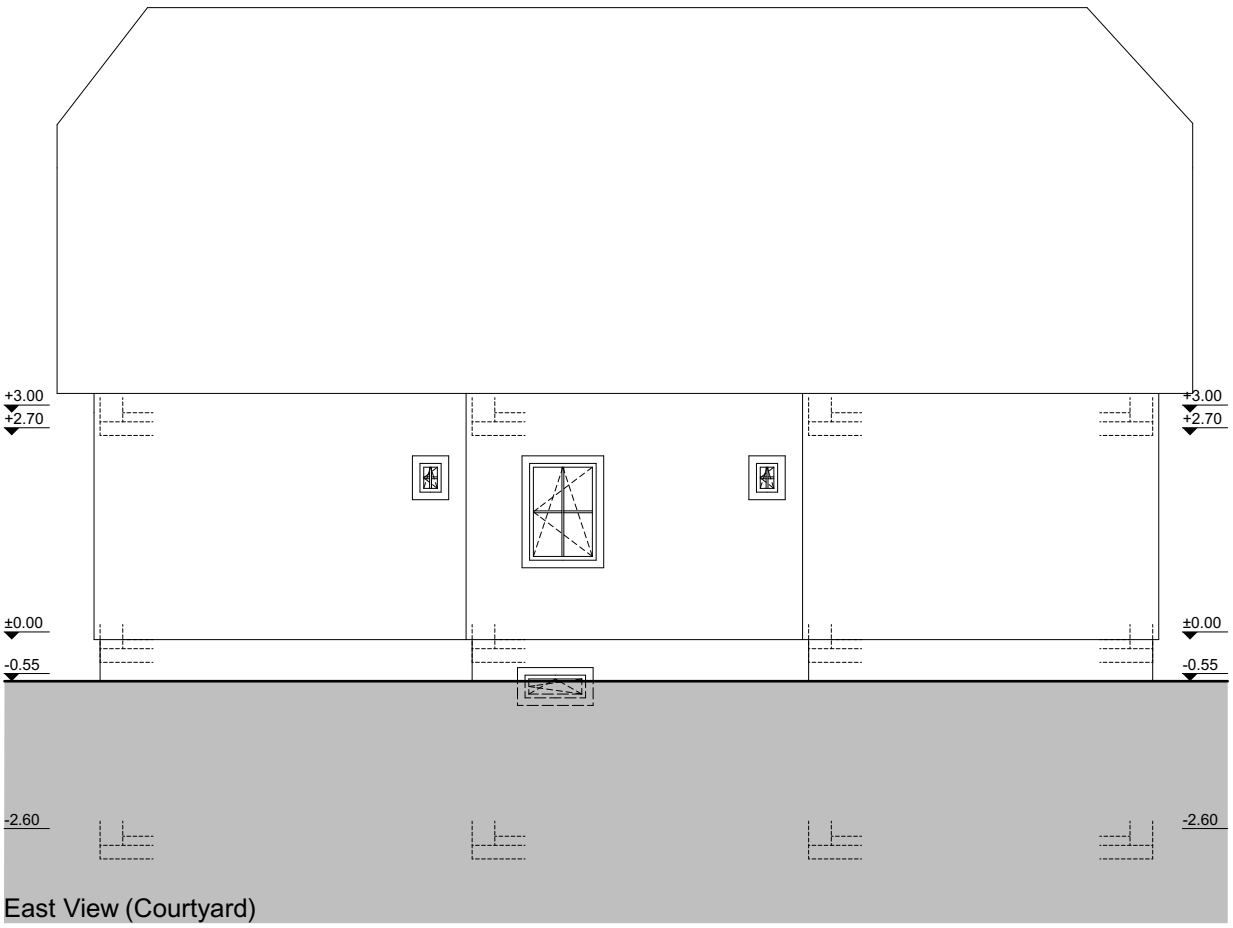
Views
M=1:100





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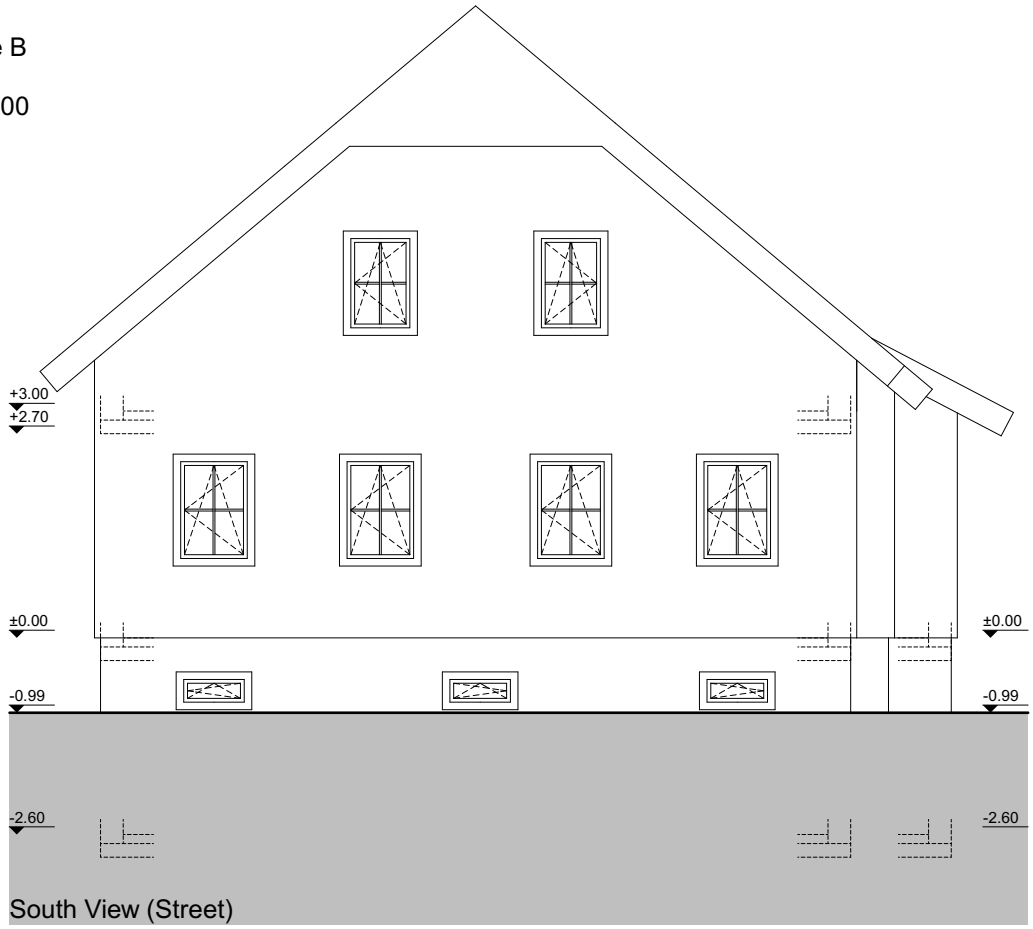
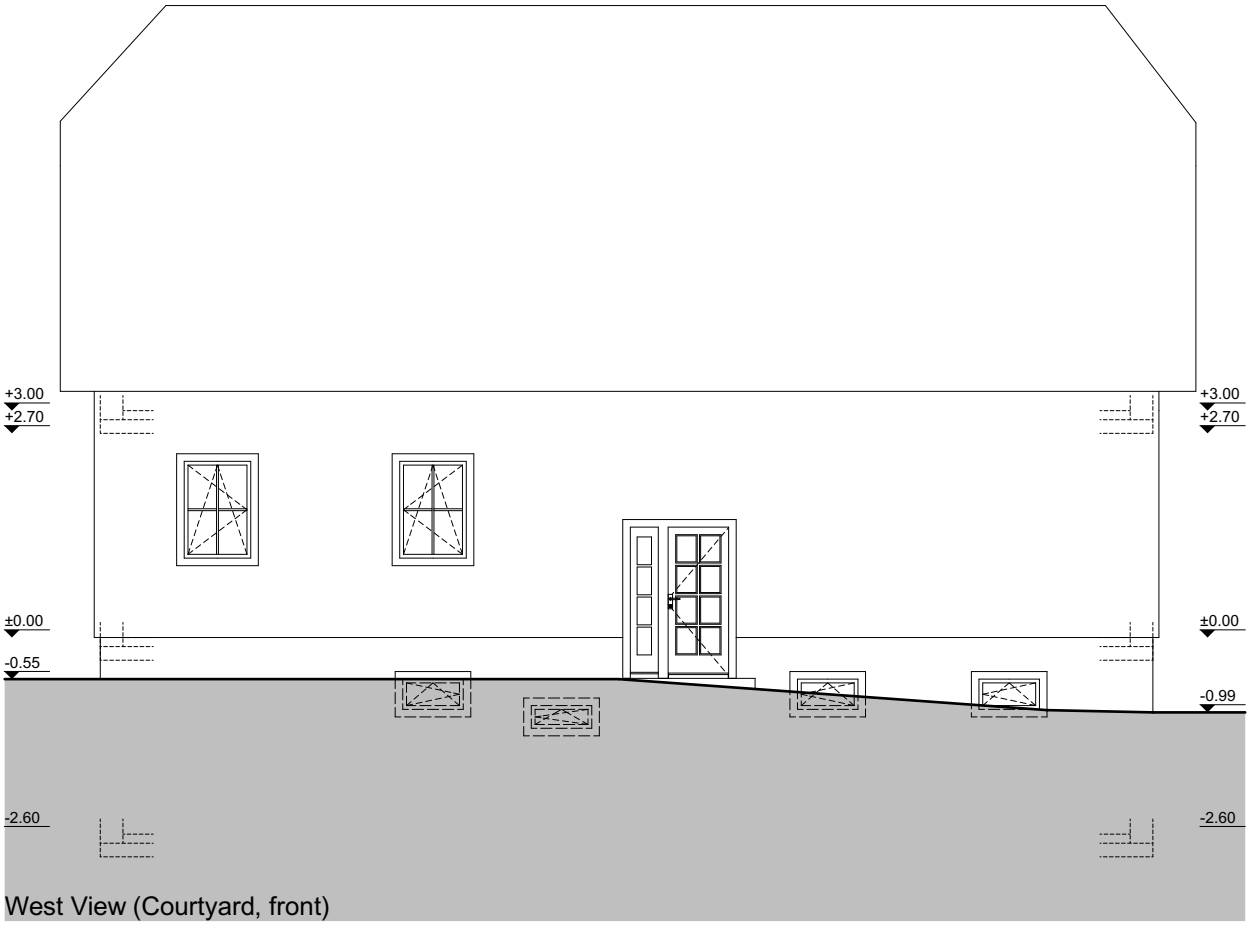
House B
Views
M=1:100



South View (Street)



West View (Courtyard, front)

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C. Energy Certificates

Following Figures are illustrations taken from ArchiPhysik based on the author's case study buildings

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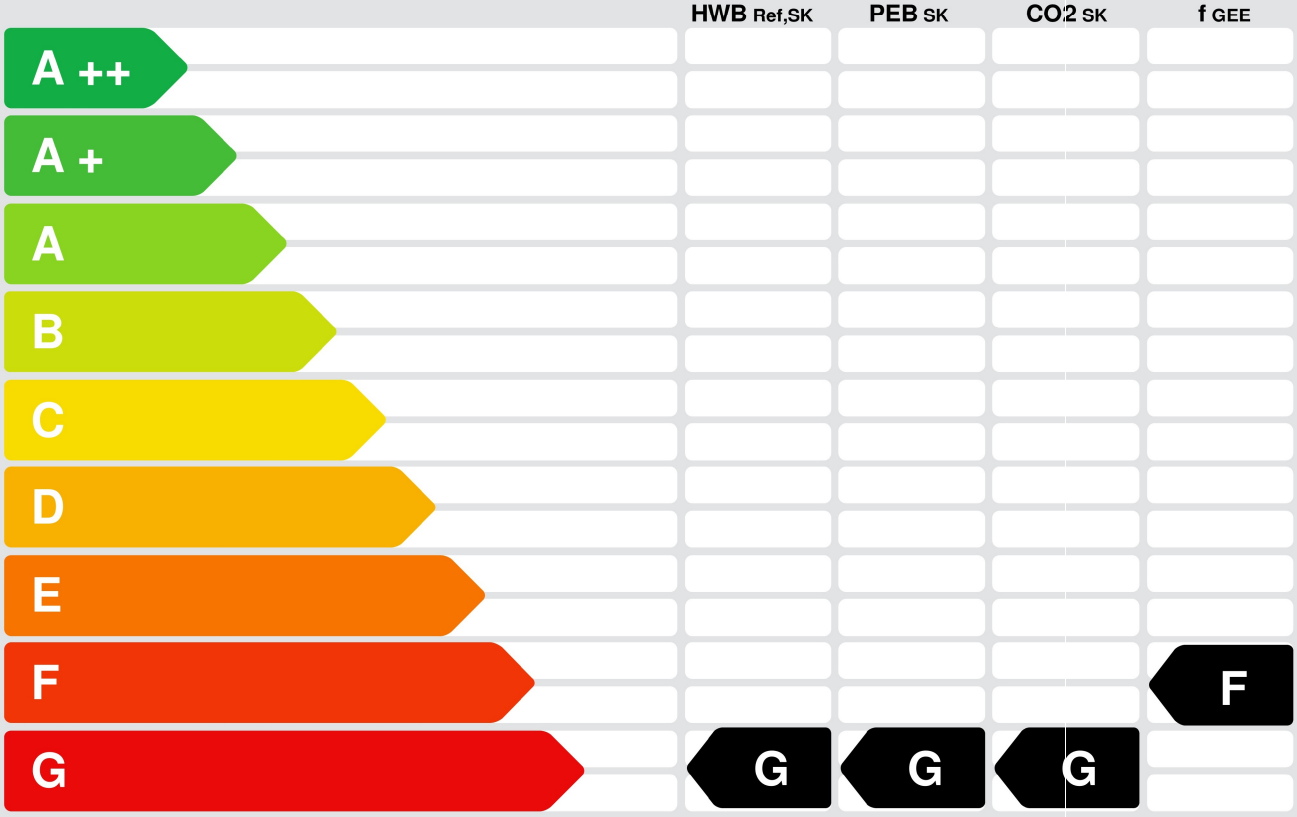
Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	House A (before 1890)		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB$_{Ref}$: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren (PEB$_{ern.}$) und einen nicht erneuerbaren (PEB$_{n.ern.}$) Anteil auf.

CO$_2$: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU über die Gesamtenergieeffizienz von Gebäuden und nach Maßgabe der NÖ BTV 2014. Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	129,90 m²	charakteristische Länge	0,67 m	mittlerer U-Wert	1,546 W/m²K
Bezugsfläche	103,92 m²	Klimaregion	N	LEK $_{T}$-Wert	173,70
Brutto-Volumen	298,77 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	443,85 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,49 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	HWB $_{Ref,RK}$	472,72	kWh/m²a
Heizwärmebedarf		HWB $_{RK}$	472,72	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB $_{RK}$	610,66	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f $_{GEE}$	3,657	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	65.105	kWh/a	HWB $_{Ref,SK}$	501,19	kWh/m²a
Heizwärmebedarf	64.892	kWh/a	HWB $_{SK}$	499,55	kWh/m²a
Warmwasserwärmebedarf	1.659	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	81.402	kWh/a	HEB $_{SK}$	626,65	kWh/m²a
Energieaufwandszahl Heizen			e $_{AWZ,H}$	1,22	
Haushaltsstrombedarf	2.134	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	83.536	kWh/a	EEB $_{SK}$	643,08	kWh/m²a
Primärenergiebedarf	99.821	kWh/a	PEB $_{SK}$	768,44	kWh/m²a
Primärenergiebedarf nicht erneuerbar	98.159	kWh/a	PEB $_{n.ern.,SK}$	755,65	kWh/m²a
Primärenergiebedarf erneuerbar	1.662	kWh/a	PEB $_{ern.,SK}$	12,79	kWh/m²a
Kohlendioxidemissionen (optional)	19.827	kg/a	CO2 $_{SK}$	152,63	kg/m²a
Gesamtenergieeffizienz-Faktor			f $_{GEE}$	3,690	
Photovoltaik-Export	0	kWh/a	PV $_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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Grundfläche und Volumen

House A (before 1890)

Brutto-Grundfläche und Brutto-Volumen

		BGF [m²]	V [m³]
Wohnen	beheizt	129,90	298,77

Wohnen

beheizt

	Formel	Höhe [m]	BGF [m²]	V [m³]
Ground floor				
Ground floor	1 x 129,90	2,30	129,90	298,77
Summe Wohnen			**129,90**	**298,77**

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Bauteilflächen

House A (before 1890) - Alle Gebäudeteile/Zonen

		m²
Flächen der thermischen Gebäudehülle		**443,85**
Opake Flächen	97,12 %	431,06
Fensterflächen	2,88 %	12,79
Wärmefluss nach oben		129,19
Wärmefluss nach unten		129,19
Andere Flächen		**109,50**
Opake Flächen	100 %	109,50
Fensterflächen	0 %	0,00

Flächen der thermischen Gebäudehülle

Wohnen — Einfamilienhäuser

				m²
Ceiling to ground 01 - tiles				**21,76**
Fläche	H	x+y	1 x 21,76	21,76
Ceiling to ground 02 - linoleum				**53,06**
Fläche	H	x+y	1 x 53,06	53,06
Ceiling to ground 03 - carpet				**27,66**
Fläche	H	x+y	1 x 27,66	27,66
Ceiling to ground 04 - laminate				**26,71**
Fläche	H	x+y	1 x 26,71	26,71
Ceiling to unheated attic				**129,19**
Fläche	H	x+y	1 x 129,19	129,19
Exterior wall 01				**155,98**
Fläche	N		1 x 4,87 * 3,45	16,80
Window 03 (small)			-1 x 0,87	-0,87
Fläche	O		1 x 16,65 * 3,45	57,44
Window 02 (middle)			-4 x 1,40	-5,60
Fläche	S		1 x 10,14 * 3,45	34,98
Window 01 (big)			-4 x 1,58	-6,32
Fläche	W		1 x 17,26 * 3,45	59,54
Exterior wall 02 to garage				**16,70**
Fläche	N		1 x 4,84 * 3,45	16,69

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			m²
Window 01 (big)	S	**4 x 1,58**	**6,32**
Window 02 (middle)	O	**4 x 1,40**	**5,60**
Window 03 (small)	N	**1 x 0,87**	**0,87**

Andere Flächen

Wohnen — Einfamilienhäuser

				m²
Interior wall 01 - 50cm				**15,27**
Fläche	N		1 x 5,14 * 2,97	15,26
Interior wall 02 - 33cm				**55,84**
Fläche	N		1 x 18,80 * 2,97	55,83
Interior wall 03 - 15cm				**38,40**
Fläche	N		1 x 12,93 * 2,97	38,40

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Ergebnisdarstellung

House A (before 1890)

Berechnungsgrundlagen

Wärmeschutz	U-Wert	EN ISO 6946:2003-10, EN ISO 10077-1:2006-12
Dampfdiffusion	Bewertung	ON B 8110-2: 2003
Schallschutz	R_w	ON B 8115-4: 2003
	$L'_{nT,w}$	ON B 8115-4: 2003
	$D_{nT,w}$	ON B 8115-4: 2003

Opake Bauteile

Erforderliche Werte werden in Klammer angeführt

Nummer	Bezeichnung	U-Wert W/m²K		Dampf-diffusion	R_w dB		$L'_{nT,w}$ dB
	Exterior wall 01	2,387	(0,35)		66	(43)	
	Ceiling to unheated attic	0,544	(0,20)	OK	54	(42)	(53)
	Ceiling to ground 01 - tiles	1,481	(0,40)	OK	66		
	Ceiling to ground 02 - linoleum	1,391	(0,40)	OK	66		
	Ceiling to ground 03 - carpet	1,274	(0,40)	OK	66		
	Ceiling to ground 04 - laminate	1,357	(0,40)	OK	66		
	Interior wall 01 - 50cm	0,923		OK	66		
	Interior wall 02 - 33cm	1,222		OK	63		
	Interior wall 03 - 15cm	1,866		OK	53		
	Exterior wall 02 to garage	1,965	(0,60)	OK	66	(60)	

Transparente Bauteile

Erforderliche Werte werden in Klammer angeführt

Nummer	Bezeichnung	U-Wert W/m²K		$U\text{-}Wert_{PNM}$ W/m²K	R_w (C; C_{tr}) dB	
	Window 01 (big)	2,710	(1,40)		0 (-; -)	(28 (-; -))
	Window 02 (middle)	2,680	(1,40)		0 (-; -)	(28 (-; -))
	Window 03 (small)	2,490	(1,40)		0 (-; -)	(28 (-; -))
	Entrance door (incl window)	1,620	(1,40)		0 (-; -)	(28 (-; -))

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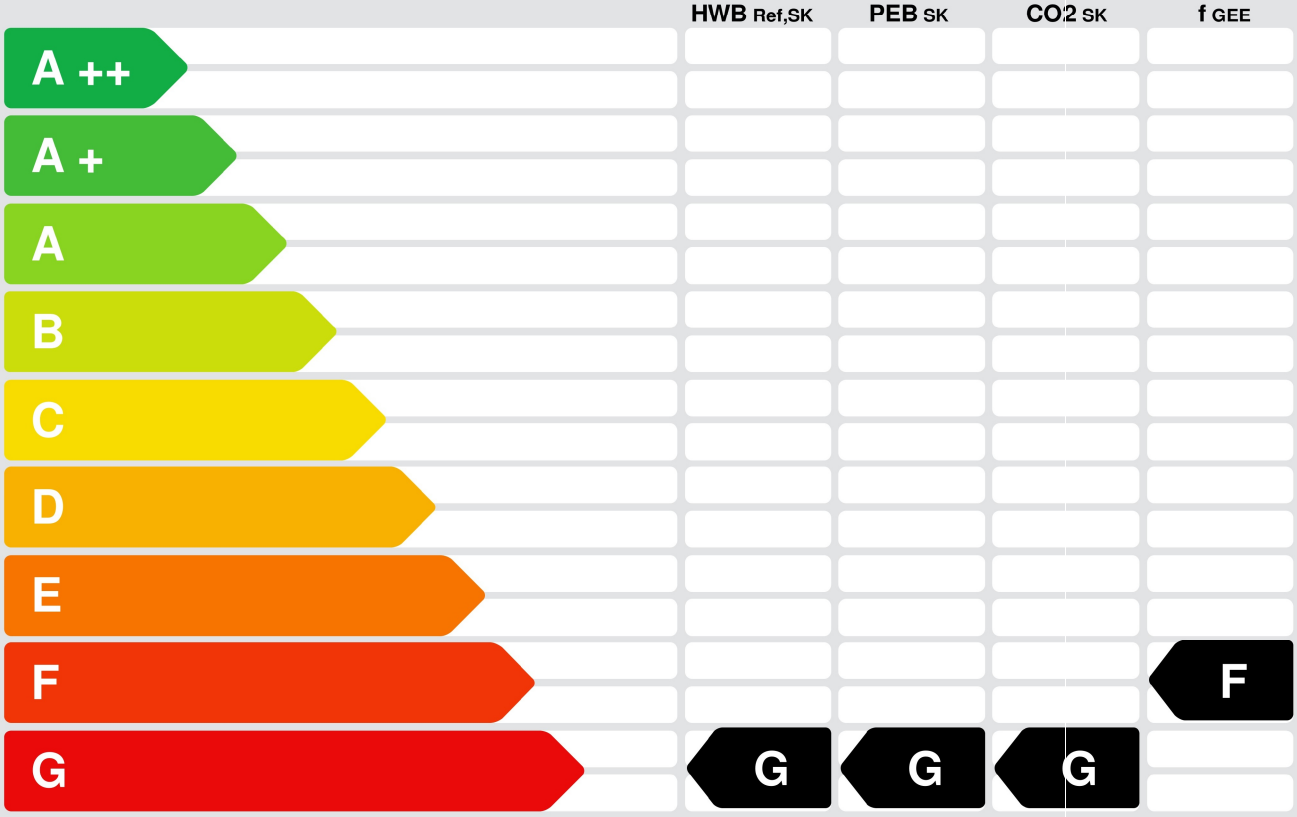
Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Sceanrio A.1.1		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB$_{Ref}$: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren (PEB$_{ern.}$) und einen nicht erneuerbaren (PEB$_{n.ern.}$) Anteil auf.

CO$_2$: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU über die Gesamtenergieeffizienz von Gebäuden und nach Maßgabe der NÖ BTV 2014. Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	129,90 m²	charakteristische Länge	0,67 m	mittlerer U-Wert	1,492 W/m²K
Bezugsfläche	103,92 m²	Klimaregion	N	LEK T-Wert	167,60
Brutto-Volumen	298,77 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	443,85 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,49 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	462,18	kWh/m²a
Heizwärmebedarf		HWB_{RK}	462,18	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	599,60	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	3,599	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	63.653	kWh/a	$HWB_{Ref,SK}$	490,01	kWh/m²a
Heizwärmebedarf	63.433	kWh/a	HWB_{SK}	488,32	kWh/m²a
Warmwasserwärmebedarf	1.659	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	79.871	kWh/a	HEB_{SK}	614,87	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,23	
Haushaltsstrombedarf	2.134	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	82.005	kWh/a	EEB_{SK}	631,29	kWh/m²a
Primärenergiebedarf	98.023	kWh/a	PEB_{SK}	754,60	kWh/m²a
Primärenergiebedarf nicht erneuerbar	96.367	kWh/a	$PEB_{n.ern.,SK}$	741,85	kWh/m²a
Primärenergiebedarf erneuerbar	1.656	kWh/a	$PEB_{ern.,SK}$	12,75	kWh/m²a
Kohlendioxidemissionen (optional)	19.465	kg/a	$CO2_{SK}$	149,85	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	3,631	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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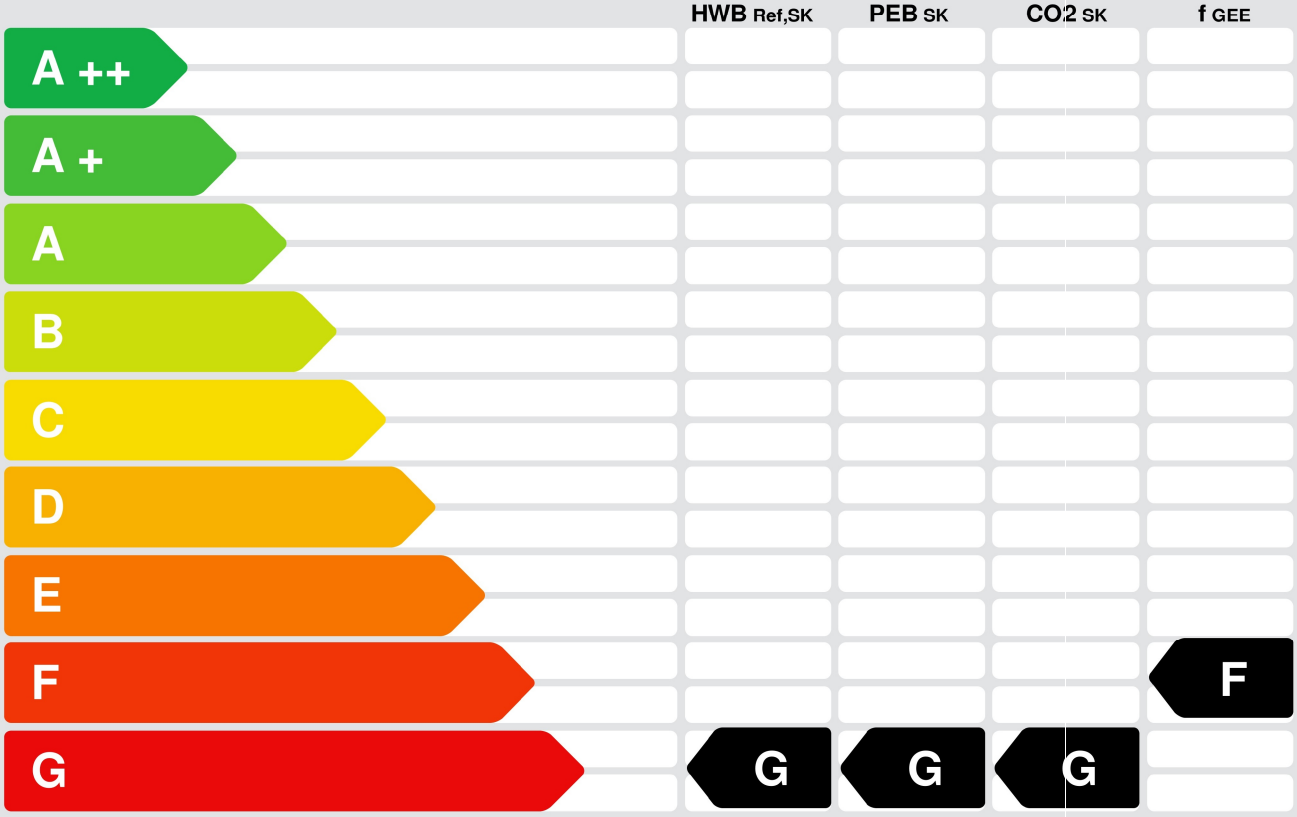
Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Sceanrio A.1.2		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB$_{Ref}$: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren (PEB$_{ern.}$) und einen nicht erneuerbaren (PEB$_{n.ern.}$) Anteil auf.

CO_2: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU über die Gesamtenergieeffizienz von Gebäuden und nach Maßgabe der NÖ BTV 2014. Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	129,90 m²	charakteristische Länge	0,67 m	mittlerer U-Wert	1,487 W/m²K
Bezugsfläche	103,92 m²	Klimaregion	N	LEK T-Wert	167,00
Brutto-Volumen	298,77 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	443,85 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,49 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	459,88	kWh/m²a
Heizwärmebedarf		HWB_{RK}	459,88	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	597,19	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	3,584	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	63.336	kWh/a	$HWB_{Ref,SK}$	487,58	kWh/m²a
Heizwärmebedarf	63.117	kWh/a	HWB_{SK}	485,89	kWh/m²a
Warmwasserwärmebedarf	1.659	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	79.537	kWh/a	HEB_{SK}	612,30	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,23	
Haushaltsstrombedarf	2.134	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	81.671	kWh/a	EEB_{SK}	628,72	kWh/m²a
Primärenergiebedarf	97.631	kWh/a	PEB_{SK}	751,58	kWh/m²a
Primärenergiebedarf nicht erneuerbar	95.976	kWh/a	$PEB_{n.ern.,SK}$	738,84	kWh/m²a
Primärenergiebedarf erneuerbar	1.655	kWh/a	$PEB_{ern.,SK}$	12,74	kWh/m²a
Kohlendioxidemissionen (optional)	19.387	kg/a	$CO2_{SK}$	149,24	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	3,615	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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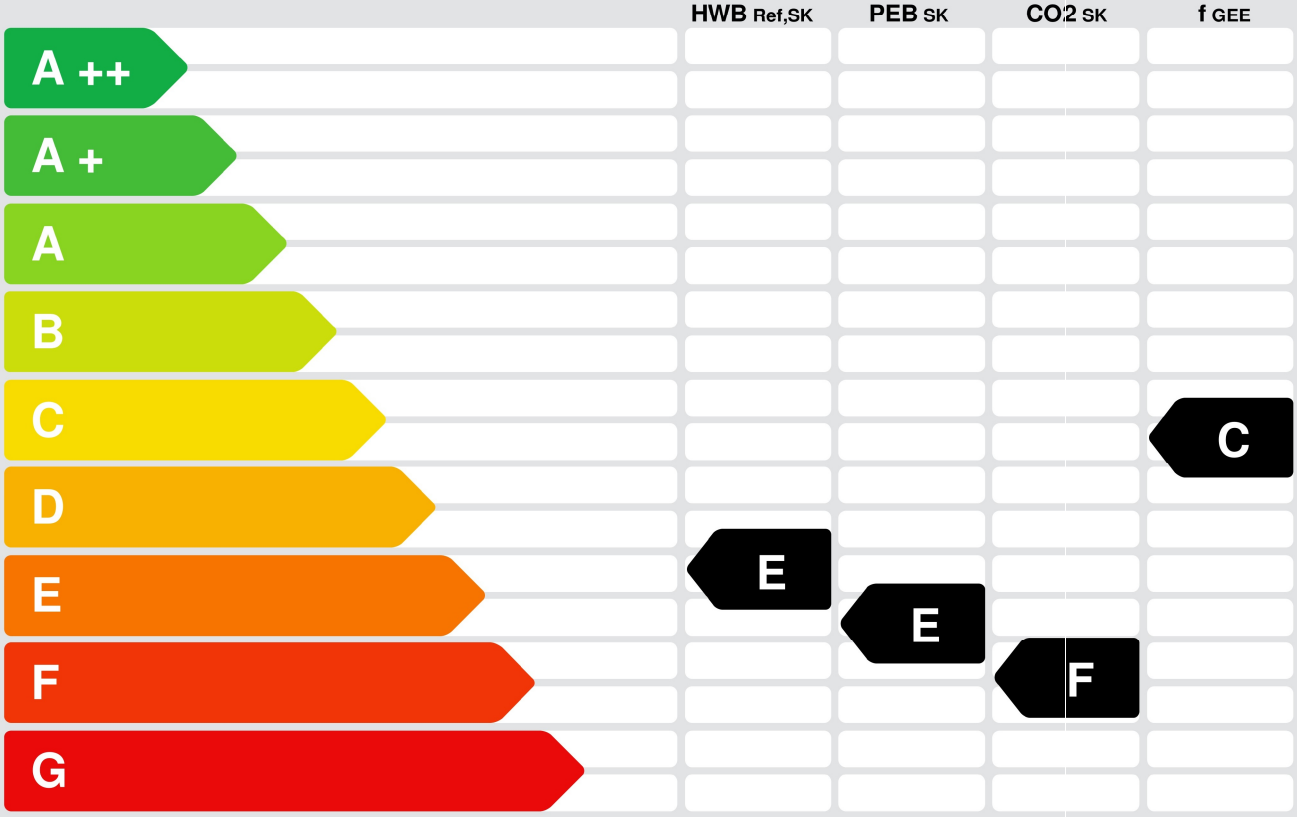
Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Scenario A.2.1		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB_{Ref}: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f_{GEE}: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren ($PEB_{ern.}$) und einen nicht erneuerbaren ($PEB_{n.ern.}$) Anteil auf.

CO_2: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	129,90 m²	charakteristische Länge	0,67 m	mittlerer U-Wert	0,533 W/m²K
Bezugsfläche	103,92 m²	Klimaregion	N	LEK T-Wert	59,90
Brutto-Volumen	298,77 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	443,85 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,49 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	153,91	kWh/m²a
Heizwärmebedarf		HWB_{RK}	153,91	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	260,01	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	1,557	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	21.197	kWh/a	$HWB_{Ref,SK}$	163,18	kWh/m²a
Heizwärmebedarf	21.007	kWh/a	HWB_{SK}	161,72	kWh/m²a
Warmwasserwärmebedarf	1.659	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	33.223	kWh/a	HEB_{SK}	255,76	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,47	
Haushaltsstrombedarf	2.134	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	35.357	kWh/a	EEB_{SK}	272,18	kWh/m²a
Primärenergiebedarf	43.138	kWh/a	PEB_{SK}	332,09	kWh/m²a
Primärenergiebedarf nicht erneuerbar	41.726	kWh/a	$PEB_{n.ern.,SK}$	321,22	kWh/m²a
Primärenergiebedarf erneuerbar	1.412	kWh/a	$PEB_{ern.,SK}$	10,87	kWh/m²a
Kohlendioxidemissionen (optional)	8.440	kg/a	$CO2_{SK}$	64,97	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	1,562	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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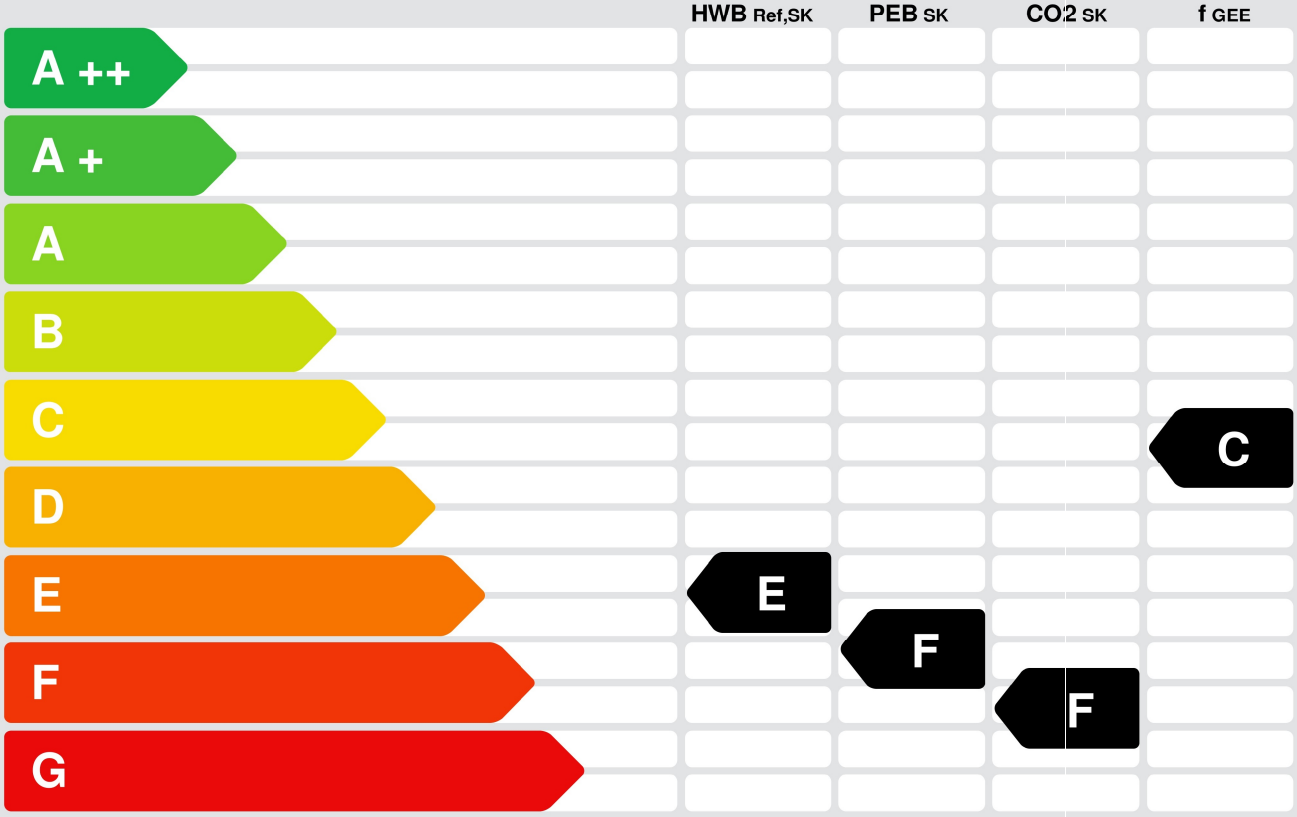
Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Scenario A.2.2		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB$_{Ref}$: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren (PEB$_{ern.}$) und einen nicht erneuerbaren (PEB$_{n.ern.}$) Anteil auf.

CO_2: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU über die Gesamtenergieeffizienz von Gebäuden und nach Maßgabe der NÖ BTV 2014. Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	129,90 m²	charakteristische Länge	0,67 m	mittlerer U-Wert	0,570 W/m²K
Bezugsfläche	103,92 m²	Klimaregion	N	LEK T-Wert	64,10
Brutto-Volumen	298,77 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	443,85 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,49 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	165,35	kWh/m²a
Heizwärmebedarf		HWB_{RK}	165,35	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	274,11	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	1,641	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	22.781	kWh/a	$HWB_{Ref,SK}$	175,37	kWh/m²a
Heizwärmebedarf	22.586	kWh/a	HWB_{SK}	173,87	kWh/m²a
Warmwasserwärmebedarf	1.659	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	35.141	kWh/a	HEB_{SK}	270,52	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,45	
Haushaltsstrombedarf	2.134	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	37.275	kWh/a	EEB_{SK}	286,95	kWh/m²a
Primärenergiebedarf	45.395	kWh/a	PEB_{SK}	349,46	kWh/m²a
Primärenergiebedarf nicht erneuerbar	43.973	kWh/a	$PEB_{n.ern.,SK}$	338,51	kWh/m²a
Primärenergiebedarf erneuerbar	1.422	kWh/a	$PEB_{ern.,SK}$	10,95	kWh/m²a
Kohlendioxidemissionen (optional)	8.893	kg/a	$CO2_{SK}$	68,46	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	1,646	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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Energieausweis für Wohngebäude

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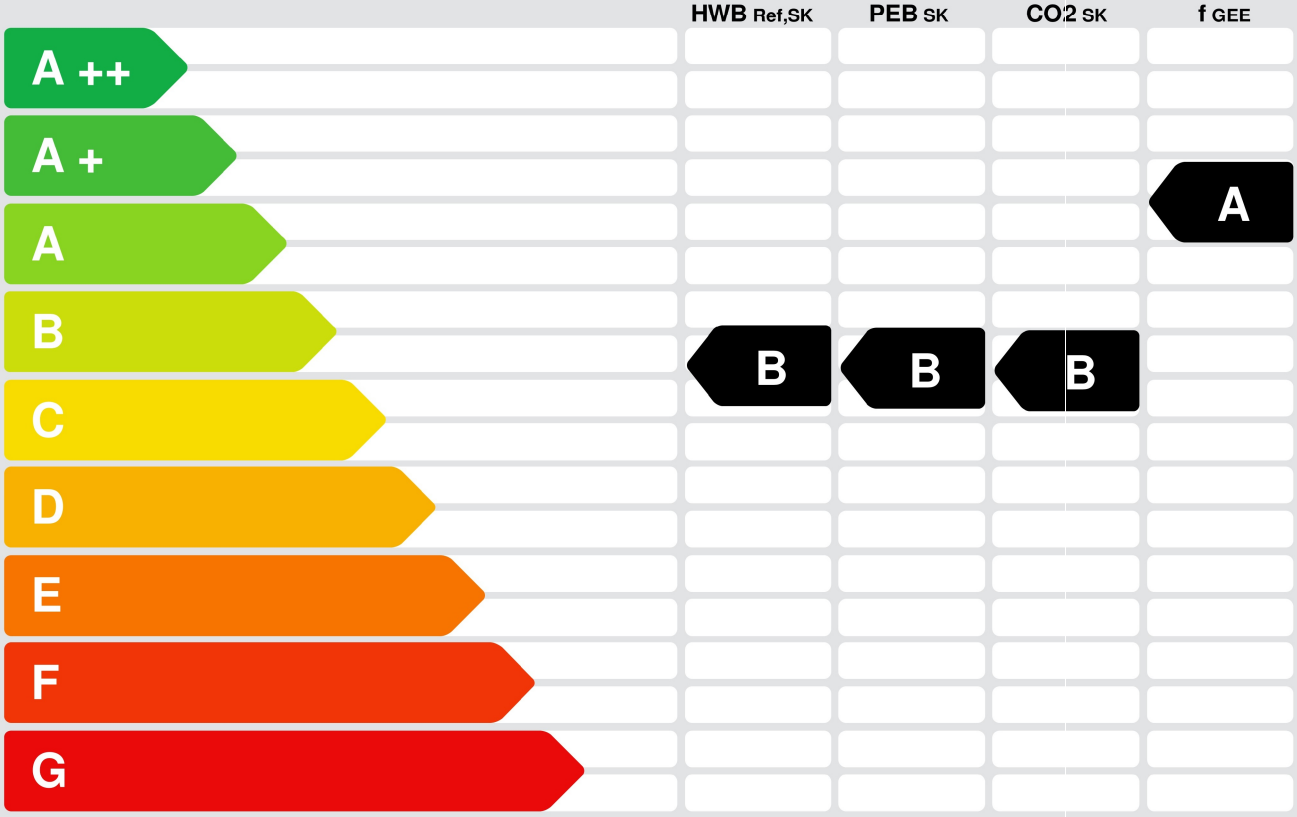
OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Scenario A.3		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB_{Ref}: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f_{GEE}: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren ($PEB_{ern.}$) und einen nicht erneuerbaren ($PEB_{n.ern.}$) Anteil auf.

CO_2: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU über die Gesamtenergieeffizienz von Gebäuden und nach Maßgabe der NÖ BTV 2014. Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	129,90 m²	charakteristische Länge	0,67 m	mittlerer U-Wert	0,160 W/m²K
Bezugsfläche	103,92 m²	Klimaregion	N	LEK T-Wert	18,00
Brutto-Volumen	298,77 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	443,85 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,49 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	45,48	kWh/m²a
Heizwärmebedarf		HWB_{RK}	45,48	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	119,89	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	0,720	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	6.282	kWh/a	$HWB_{Ref,SK}$	48,36	kWh/m²a
Heizwärmebedarf	6.129	kWh/a	HWB_{SK}	47,18	kWh/m²a
Warmwasserwärmebedarf	1.659	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	13.921	kWh/a	HEB_{SK}	107,17	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,79	
Haushaltsstrombedarf	2.134	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	16.055	kWh/a	EEB_{SK}	123,60	kWh/m²a
Primärenergiebedarf	20.438	kWh/a	PEB_{SK}	157,34	kWh/m²a
Primärenergiebedarf nicht erneuerbar	19.120	kWh/a	$PEB_{n.ern.,SK}$	147,19	kWh/m²a
Primärenergiebedarf erneuerbar	1.318	kWh/a	$PEB_{ern.,SK}$	10,15	kWh/m²a
Kohlendioxidemissionen (optional)	3.878	kg/a	$CO2_{SK}$	29,86	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	0,711	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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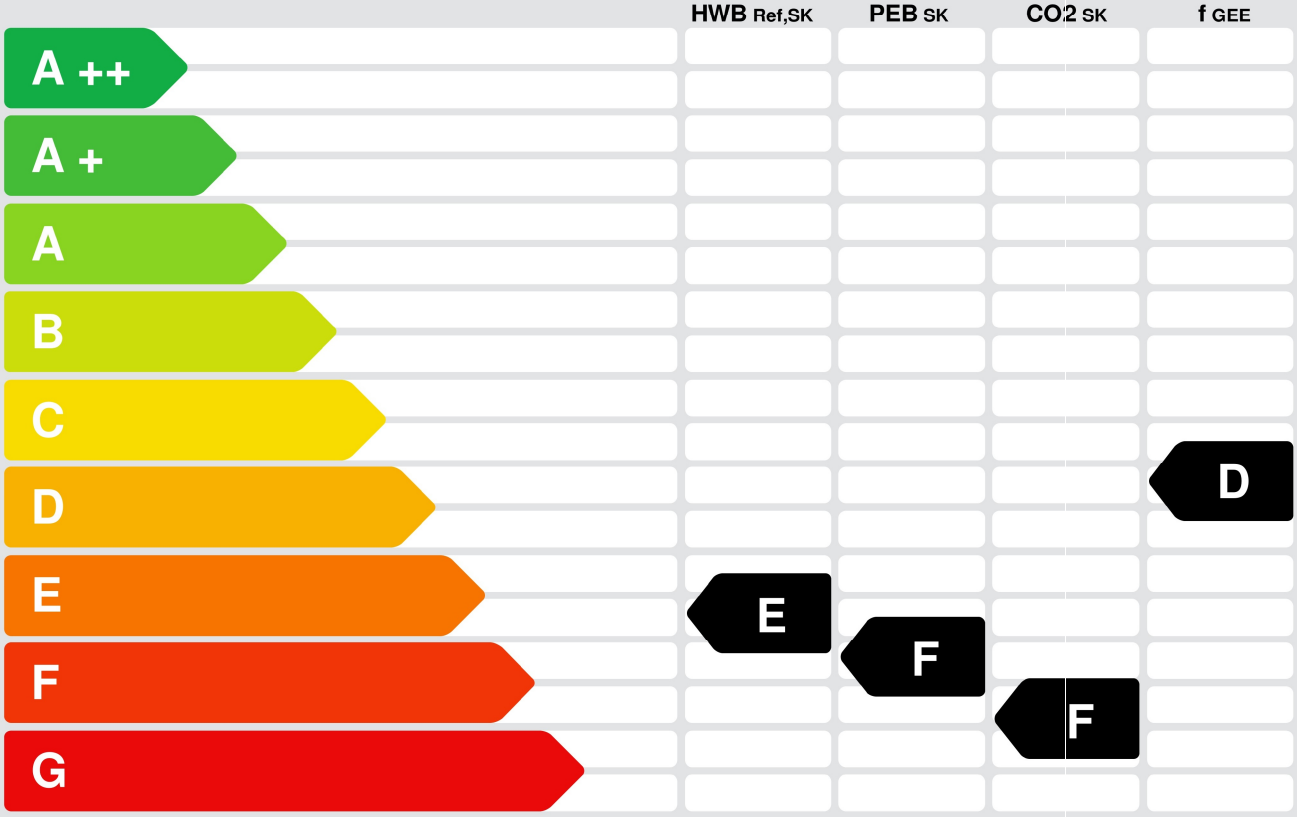
Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	House B (1990)		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB$_{Ref}$: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren (PEB$_{ern.}$) und einen nicht erneuerbaren (PEB$_{n.ern.}$) Anteil auf.

CO_2: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	150,42 m²	charakteristische Länge	0,87 m	mittlerer U-Wert	0,671 W/m²K
Bezugsfläche	120,33 m²	Klimaregion	N	LEK T-Wert	70,10
Brutto-Volumen	406,13 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	469,07 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,15 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	176,95	kWh/m²a
Heizwärmebedarf		HWB_{RK}	176,95	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	279,50	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	1,918	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	28.206	kWh/a	$HWB_{Ref,SK}$	187,52	kWh/m²a
Heizwärmebedarf	27.846	kWh/a	HWB_{SK}	185,12	kWh/m²a
Warmwasserwärmebedarf	1.921	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	41.460	kWh/a	HEB_{SK}	275,63	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,39	
Haushaltsstrombedarf	2.471	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	43.931	kWh/a	EEB_{SK}	292,06	kWh/m²a
Primärenergiebedarf	53.470	kWh/a	PEB_{SK}	355,47	kWh/m²a
Primärenergiebedarf nicht erneuerbar	51.819	kWh/a	$PEB_{n.ern.,SK}$	344,50	kWh/m²a
Primärenergiebedarf erneuerbar	1.651	kWh/a	$PEB_{ern.,SK}$	10,98	kWh/m²a
Kohlendioxidemissionen (optional)	10.480	kg/a	$CO2_{SK}$	69,67	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	1,927	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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Brutto-Grundfläche und Brutto-Volumen

		BGF [m²]	V [m³]
Wohnen	beheizt	150,42	406,13

Wohnen

beheizt

	Formel	Höhe [m]	BGF [m²]	V [m³]
Ground floor				
Ground floor	1 x 150,42	2,70	150,42	406,13
Summe Wohnen			**150,42**	**406,13**

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Bauteilflächen

House B (1990) - Alle Gebäudeteile/Zonen

		m²
Flächen der thermischen Gebäudehülle		**469,07**
Opake Flächen	95,96 %	450,11
Fensterflächen	4,04 %	18,96
Wärmefluss nach oben		150,42
Wärmefluss nach unten		150,42
Andere Flächen		**164,94**
Opake Flächen	100 %	164,94
Fensterflächen	0 %	0,00

Flächen der thermischen Gebäudehülle

Wohnen — Einfamilienhäuser

				m²
Ceiling to unheated attic				**150,42**
Fläche	H	x+y	1 x 150,42	150,42
Ceiling to unheated basement 01 - tiles				**46,52**
Fläche	H	x+y	1 x 46,52	46,52
Ceiling to unheated basement 02 - linole				**33,76**
Fläche	H	x+y	1 x 33,76	33,76
Ceiling to unheated basement 03 - carpe				**45,85**
Fläche	H	x+y	1 x 45,85	45,85
Ceiling to unheated basement 04 - lamin				**24,29**
Fläche	H	x+y	1 x 24,29	24,29
Entrance door (incl window)	W		**1 x 2,40**	**2,40**
Exterior wall 01				**149,27**
Fläche	N		1 x 11,41 * 3,30	37,65
Window 01 (big)			-3 x 1,60	-4,80
Fläche	O		1 x 14,08 * 3,30	46,46
Window 02 (small)			-2 x 0,28	-0,56
Window 01 (big)			-1 x 1,60	-1,60
Fläche	S		1 x 11,41 * 3,30	37,65
Window 01 (big)			-4 x 1,60	-6,40
Fläche	W		1 x 14,08 * 3,30	46,46

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Window 01 (big)		-2 x 1,60	-3,20
Entrance door (incl window)		-1 x 2,40	-2,40
			m²
Window 01 (big)	N	**3 x 1,60**	**4,80**
			m²
Window 01 (big)	O	**1 x 1,60**	**1,60**
			m²
Window 01 (big)	S	**4 x 1,60**	**6,40**
			m²
Window 01 (big)	W	**2 x 1,60**	**3,20**
			m²
Window 02 (small)	O	**2 x 0,28**	**0,56**

Andere Flächen

Wohnen				Einfamilienhäuser
				m²
Interior wall 01 - 25				**61,42**
Fläche	N		1 x 21,78 * 2,82	61,41
				m²
Interior wall 02 - 10				**103,52**
Fläche	N		1 x 36,71 * 2,82	103,52

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Ergebnisdarstellung

House B (1990)

Berechnungsgrundlagen

Wärmeschutz	U-Wert	EN ISO 6946:2003-10, EN ISO 10077-1:2006-12
Dampfdiffusion	Bewertung	ON B 8110-2: 2003
Schallschutz	R_w	ON B 8115-4: 2003
	$L'_{nT,w}$	ON B 8115-4: 2003
	$D_{nT,w}$	ON B 8115-4: 2003

Opake Bauteile

Erforderliche Werte werden in Klammer angeführt

Nummer	Bezeichnung	U-Wert W/m²K		Dampf-diffusion	R_w dB		$L'_{nT,w}$ dB
	Exterior wall 01	**0,357**	*(0,35)*	**OK**	**62**	*(43)*	
	Ceiling to unheated attic	**0,920**	*(0,20)*	**OK**		*(42)*	*(53)*
	Ceiling to unheated basement 01 - tiles	**0,821**	*(0,40)*	**OK**		*(58)*	*(48)*
	Ceiling to unheated basement 02 - linoleum	**0,792**	*(0,40)*	**OK**		*(58)*	*(48)*
	Ceiling to unheated basement 03 - carpet	**0,753**	*(0,40)*	**OK**		*(58)*	*(48)*
	Ceiling to unheated basement 04 - laminate	**0,781**	*(0,40)*	**OK**	**60**	*(58)*	*(48)*
	Interior wall 01 - 25	**1,742**		**OK**	**61**		
	Interior wall 02 - 10	**2,433**		**OK**	**50**		

Transparente Bauteile

Erforderliche Werte werden in Klammer angeführt

Nummer	Bezeichnung	U-Wert W/m²K		U-Wert PNM W/m²K	R_w (C; C_{tr}) dB	
	Window 01 (big)	**2,710**	*(1,40)*		**0 (-; -)**	*(28 (-; -))*
	Window 02 (small)	**2,120**	*(1,40)*		**0 (-; -)**	*(28 (-; -))*
	Entrance door (incl window)	**1,860**	*(1,40)*		**0 (-; -)**	*(28 (-; -))*

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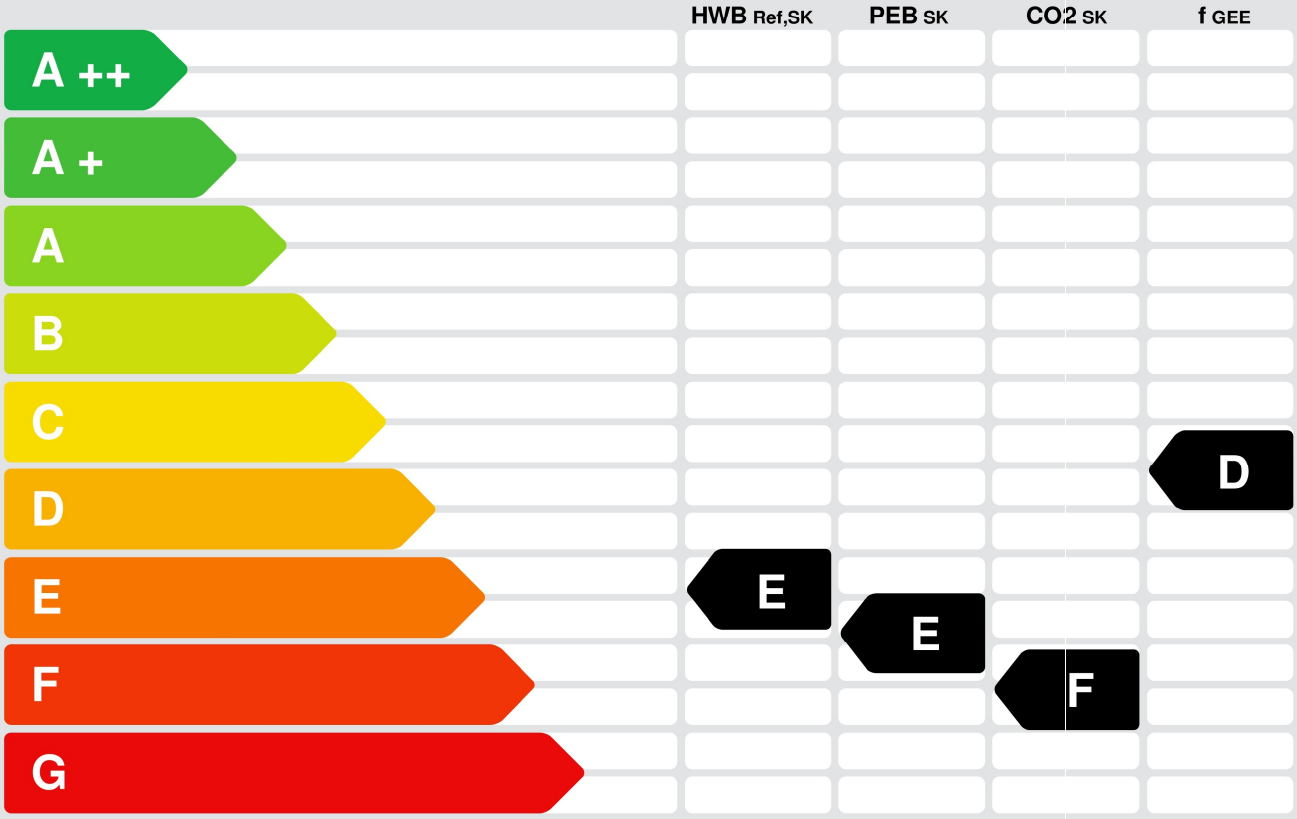
Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Scenario B.1.1		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB$_{Ref}$: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren (PEB$_{ern.}$) und einen nicht erneuerbaren (PEB$_{n.ern.}$) Anteil auf.

CO_2: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU über die Gesamtenergieeffizienz von Gebäuden und nach Maßgabe der NÖ BTV 2014. Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	150,42 m²	charakteristische Länge	0,87 m	mittlerer U-Wert	0,603 W/m²K
Bezugsfläche	120,33 m²	Klimaregion	N	LEK T-Wert	63,00
Brutto-Volumen	406,13 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	469,07 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,15 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	163,11	kWh/m²a
Heizwärmebedarf		HWB_{RK}	163,11	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	264,20	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	1,821	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	26.024	kWh/a	$HWB_{Ref,SK}$	173,01	kWh/m²a
Heizwärmebedarf	25.651	kWh/a	HWB_{SK}	170,53	kWh/m²a
Warmwasserwärmebedarf	1.921	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	39.057	kWh/a	HEB_{SK}	259,65	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,42	
Haushaltsstrombedarf	2.471	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	41.528	kWh/a	EEB_{SK}	276,08	kWh/m²a
Primärenergiebedarf	50.647	kWh/a	PEB_{SK}	336,70	kWh/m²a
Primärenergiebedarf nicht erneuerbar	49.005	kWh/a	$PEB_{n.ern.,SK}$	325,79	kWh/m²a
Primärenergiebedarf erneuerbar	1.642	kWh/a	$PEB_{ern.,SK}$	10,92	kWh/m²a
Kohlendioxidemissionen (optional)	9.912	kg/a	$CO2_{SK}$	65,89	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	1,828	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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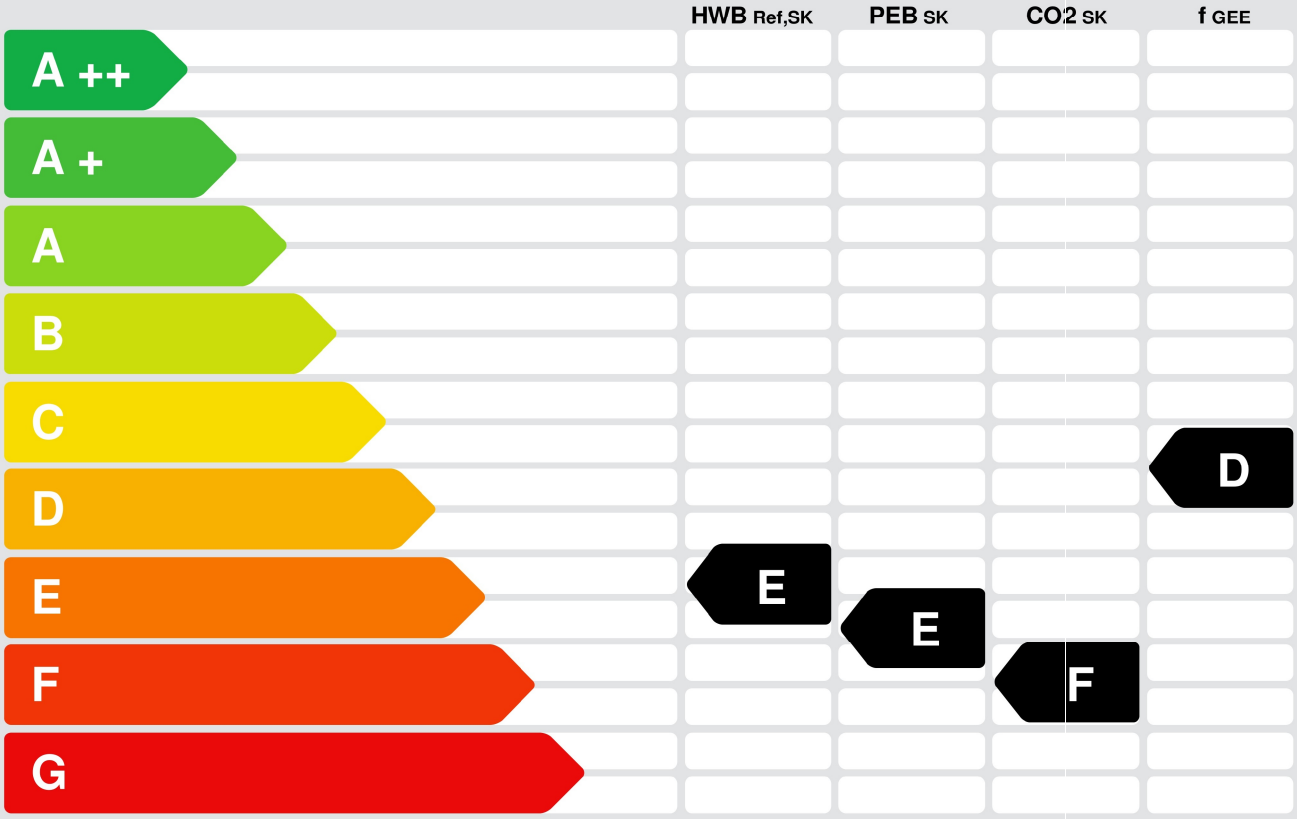
Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Scenario B.1.2		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB$_{Ref}$: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren (PEB$_{ern.}$) und einen nicht erneuerbaren (PEB$_{n.ern.}$) Anteil auf.

CO$_2$: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU über die Gesamtenergieeffizienz von Gebäuden und nach Maßgabe der NÖ BTV 2014. Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	150,42 m²	charakteristische Länge	0,87 m	mittlerer U-Wert	0,597 W/m²K
Bezugsfläche	120,33 m²	Klimaregion	N	LEK T-Wert	62,40
Brutto-Volumen	406,13 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	469,07 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,15 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	160,84	kWh/m²a
Heizwärmebedarf		HWB_{RK}	160,84	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	261,68	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	1,803	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	25.652	kWh/a	$HWB_{Ref,SK}$	170,54	kWh/m²a
Heizwärmebedarf	25.283	kWh/a	HWB_{SK}	168,08	kWh/m²a
Warmwasserwärmebedarf	1.921	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	38.636	kWh/a	HEB_{SK}	256,86	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,42	
Haushaltsstrombedarf	2.471	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	41.107	kWh/a	EEB_{SK}	273,28	kWh/m²a
Primärenergiebedarf	50.153	kWh/a	PEB_{SK}	333,42	kWh/m²a
Primärenergiebedarf nicht erneuerbar	48.512	kWh/a	$PEB_{n.ern.,SK}$	322,51	kWh/m²a
Primärenergiebedarf erneuerbar	1.641	kWh/a	$PEB_{ern.,SK}$	10,91	kWh/m²a
Kohlendioxidemissionen (optional)	9.812	kg/a	$CO2_{SK}$	65,23	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	1,809	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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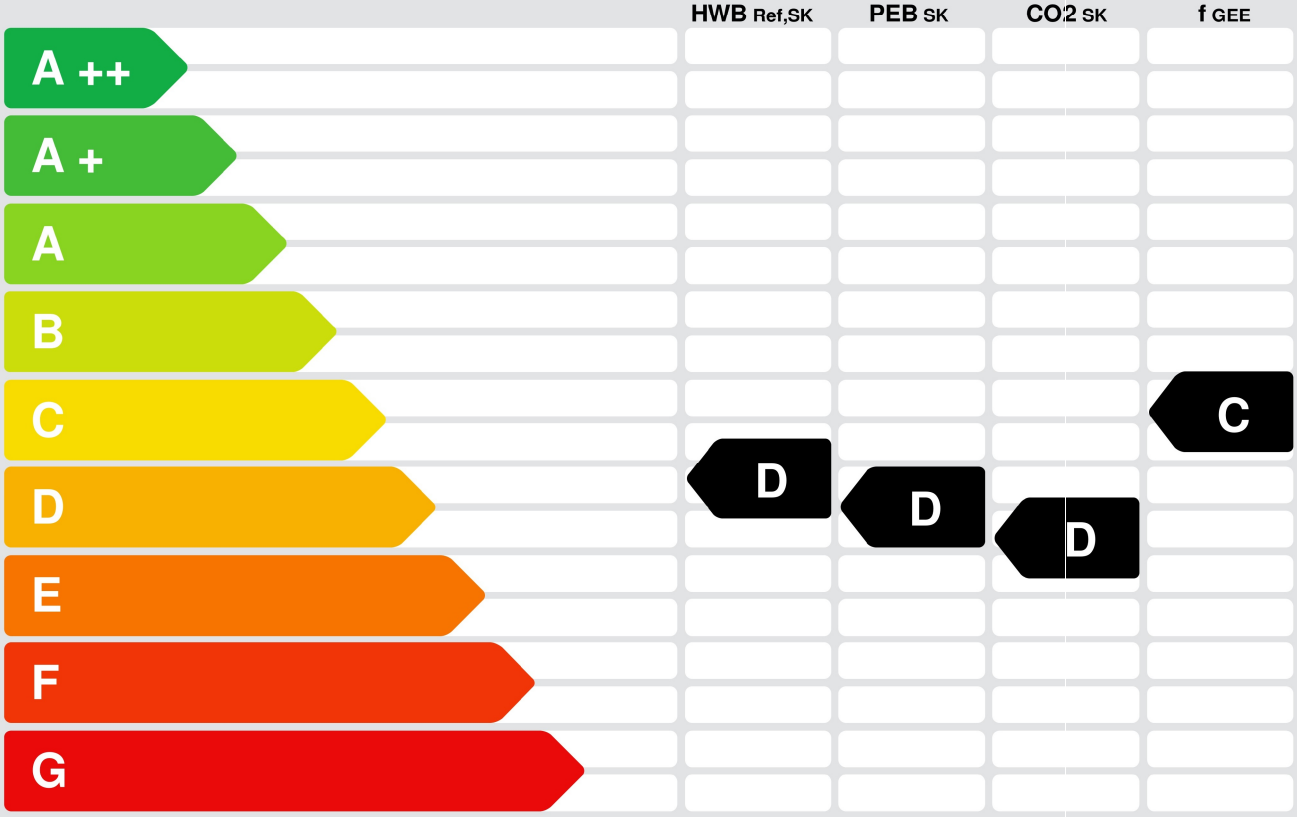
Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Scenario B.2.1		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB$_{Ref}$: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren (PEB$_{ern.}$) und einen nicht erneuerbaren (PEB$_{n.ern.}$) Anteil auf.

CO_2: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU über die Gesamtenergieeffizienz von Gebäuden und nach Maßgabe der NÖ BTV 2014. Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	150,42 m²	charakteristische Länge	0,87 m	mittlerer U-Wert	0,414 W/m²K
Bezugsfläche	120,33 m²	Klimaregion	N	LEK T-Wert	43,30
Brutto-Volumen	406,13 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	469,07 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,15 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	104,76	kWh/m²a
Heizwärmebedarf		HWB_{RK}	104,76	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	196,15	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	1,346	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	16.730	kWh/a	$HWB_{Ref,SK}$	111,22	kWh/m²a
Heizwärmebedarf	16.402	kWh/a	HWB_{SK}	109,04	kWh/m²a
Warmwasserwärmebedarf	1.921	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	28.283	kWh/a	HEB_{SK}	188,03	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,54	
Haushaltsstrombedarf	2.471	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	30.754	kWh/a	EEB_{SK}	204,45	kWh/m²a
Primärenergiebedarf	37.993	kWh/a	PEB_{SK}	252,58	kWh/m²a
Primärenergiebedarf nicht erneuerbar	36.389	kWh/a	$PEB_{n.ern.,SK}$	241,92	kWh/m²a
Primärenergiebedarf erneuerbar	1.604	kWh/a	$PEB_{ern.,SK}$	10,66	kWh/m²a
Kohlendioxidemissionen (optional)	7.367	kg/a	$CO2_{SK}$	48,97	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	1,349	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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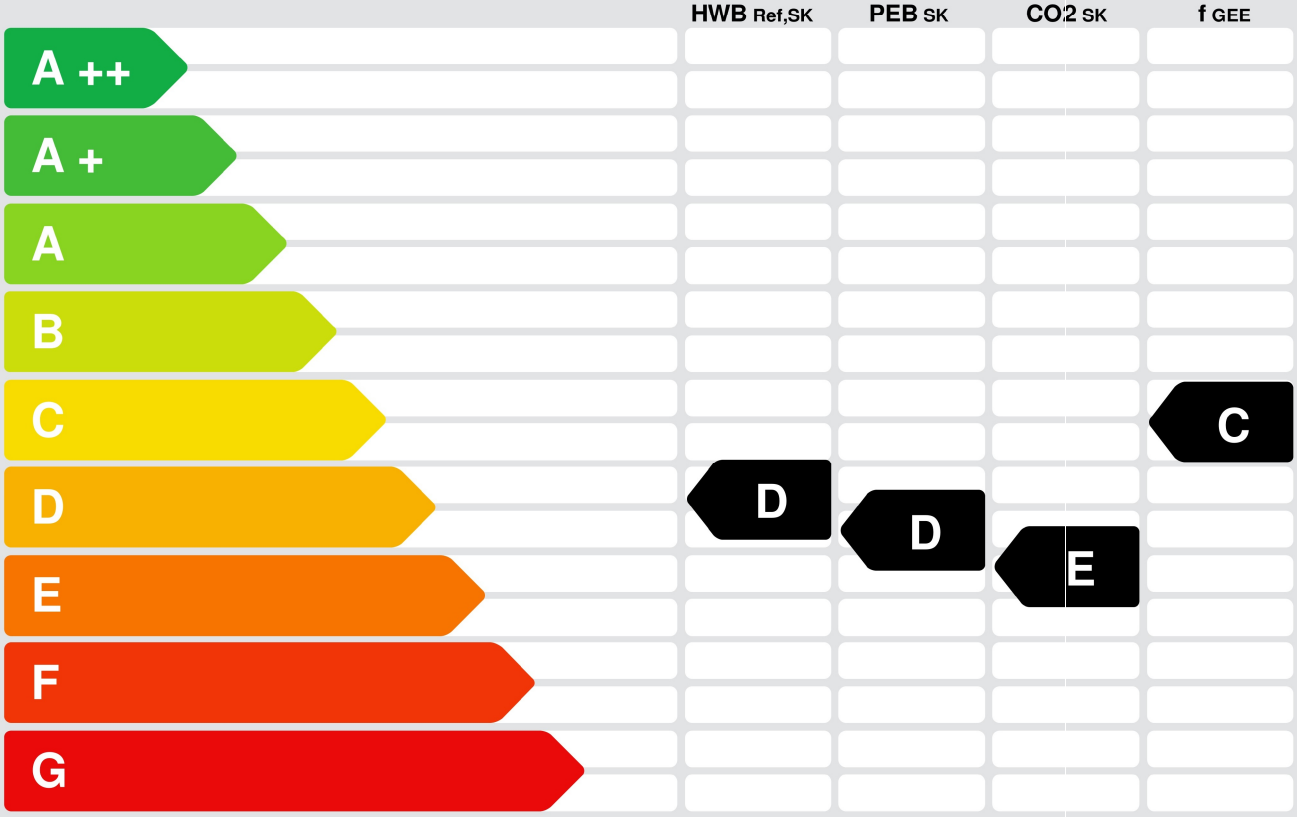
Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Scenario B.2.2		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



HWB$_{Ref}$: Der **Referenz-Heizwärmebedarf** ist jene Wärmemenge, die in den Räumen bereitgestellt werden muss, um diese auf einer normativ geforderten Raumtemperatur, ohne Berücksichtigung allfälliger Erträge aus Wärmerückgewinnung, zu halten.

WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren (PEB$_{ern.}$) und einen nicht erneuerbaren (PEB$_{n.ern.}$) Anteil auf.

CO_2: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

Alle Werte gelten unter der Annahme eines normierten BenutzerInnenverhaltens. Sie geben den Jahresbedarf pro Quadratmeter beheizter Brutto-Grundfläche an.

Dieser Energieausweis entspricht den Vorgaben der Richtlinie 6 „Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2010/31/EU über die Gesamtenergieeffizienz von Gebäuden und nach Maßgabe der NÖ BTV 2014. Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	150,42 m²	charakteristische Länge	0,87 m	mittlerer U-Wert	0,454 W/m²K
Bezugsfläche	120,33 m²	Klimaregion	N	LEK T-Wert	47,40
Brutto-Volumen	406,13 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	469,07 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,15 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	115,65	kWh/m²a
Heizwärmebedarf		HWB_{RK}	115,65	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	209,29	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	1,436	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	18.487	kWh/a	$HWB_{Ref,SK}$	122,90	kWh/m²a
Heizwärmebedarf	18.146	kWh/a	HWB_{SK}	120,64	kWh/m²a
Warmwasserwärmebedarf	1.921	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	30.360	kWh/a	HEB_{SK}	201,83	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,51	
Haushaltsstrombedarf	2.471	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	32.831	kWh/a	EEB_{SK}	218,26	kWh/m²a
Primärenergiebedarf	40.432	kWh/a	PEB_{SK}	268,79	kWh/m²a
Primärenergiebedarf nicht erneuerbar	38.821	kWh/a	$PEB_{n.ern.,SK}$	258,08	kWh/m²a
Primärenergiebedarf erneuerbar	1.611	kWh/a	$PEB_{ern.,SK}$	10,71	kWh/m²a
Kohlendioxidemissionen (optional)	7.857	kg/a	$CO2_{SK}$	52,23	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	1,440	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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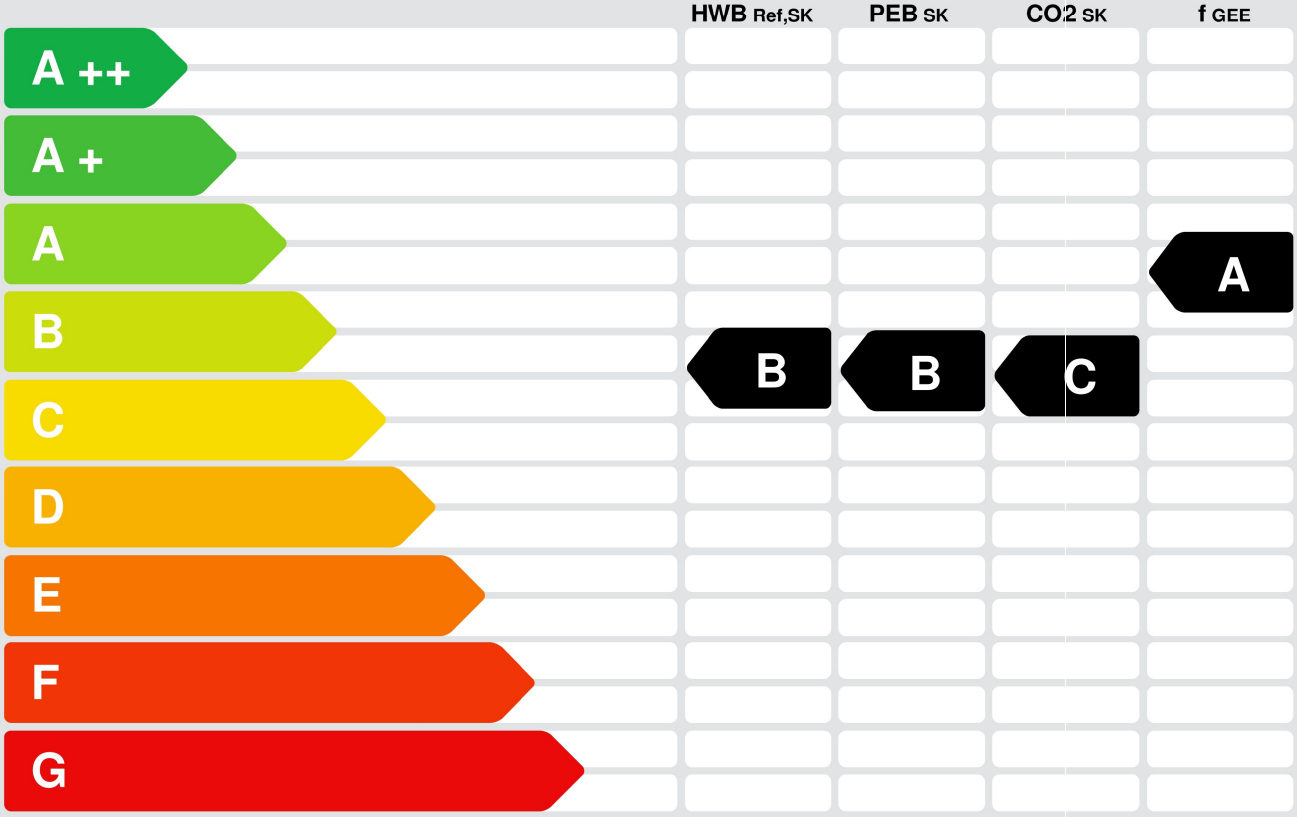
OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Scenario B.3		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



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WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

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EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	150,42 m²	charakteristische Länge	0,87 m	mittlerer U-Wert	0,181 W/m²K
Bezugsfläche	120,33 m²	Klimaregion	N	LEK T-Wert	18,90
Brutto-Volumen	406,13 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	469,07 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,15 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	k.A.	$HWB_{Ref,RK}$	46,29	kWh/m²a
Heizwärmebedarf		HWB_{RK}	46,29	kWh/m²a
End-/Lieferenergiebedarf	k.A.	E/LEB_{RK}	121,58	kWh/m²a
Gesamtenergieeffizienz-Faktor	k.A.	f_{GEE}	0,838	
Erneuerbarer Anteil	k.A.			

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	7.401	kWh/a	$HWB_{Ref,SK}$	49,20	kWh/m²a
Heizwärmebedarf	7.120	kWh/a	HWB_{SK}	47,33	kWh/m²a
Warmwasserwärmebedarf	1.921	kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	16.410	kWh/a	HEB_{SK}	109,09	kWh/m²a
Energieaufwandszahl Heizen			$e_{AWZ,H}$	1,81	
Haushaltsstrombedarf	2.471	kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	18.881	kWh/a	EEB_{SK}	125,52	kWh/m²a
Primärenergiebedarf	24.053	kWh/a	PEB_{SK}	159,91	kWh/m²a
Primärenergiebedarf nicht erneuerbar	22.488	kWh/a	$PEB_{n.ern.,SK}$	149,50	kWh/m²a
Primärenergiebedarf erneuerbar	1.565	kWh/a	$PEB_{ern.,SK}$	10,41	kWh/m²a
Kohlendioxidemissionen (optional)	4.562	kg/a	$CO2_{SK}$	30,33	kg/m²a
Gesamtenergieeffizienz-Faktor			f_{GEE}	0,831	
Photovoltaik-Export	0	kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

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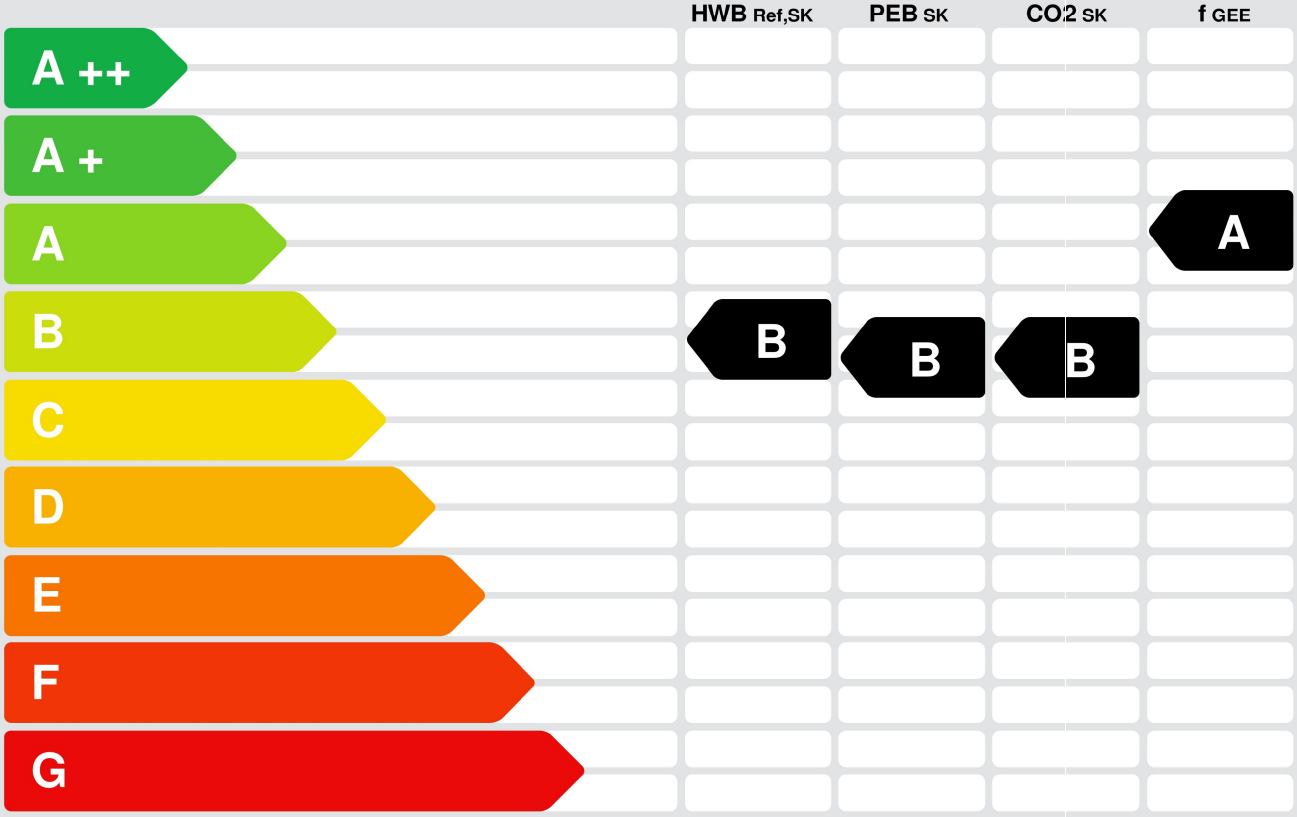
OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

BEZEICHNUNG	Scenario C		
Gebäude(-teil)	Wohnen	Baujahr	
Nutzungsprofil	Einfamilienhäuser	Letzte Veränderung	
Straße	Zwettler Straße 8	Katastralgemeinde	Langenlois
PLZ/Ort	3550 Langenlois	KG-Nr.	12215
Grundstücksnr.	435/1	Seehöhe	223 m

SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZ-FAKTOR



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WWWB: Der **Warmwasserwärmebedarf** ist in Abhängigkeit der Gebäudekategorie als flächenbezogener Defaultwert festgelegt.

HEB: Beim **Heizenergiebedarf** werden zusätzlich zum Heiz- und Warmwasserwärmebedarf die Verluste des gebäudetechnischen Systems berücksichtigt, dazu zählen insbesondere die Verluste der Wärmebereitstellung, der Wärmeverteilung, der Wärmespeicherung und der Wärmeabgabe sowie allfälliger Hilfsenergie.

HHSB: Der **Haushaltsstrombedarf** ist als flächenbezogener Defaultwert festgelegt. Er entspricht in etwa dem durchschnittlichen flächenbezogenen Stromverbrauch eines österreichischen Haushalts.

EEB: Der **Endenergiebedarf** umfasst zusätzlich zum Heizenergiebedarf den Haushaltsstrombedarf, abzüglich allfälliger Endenergieerträge und zuzüglich eines dafür notwendigen Hilfsenergiebedarfs. Der Endenergiebedarf entspricht jener Energiemenge, die eingekauft werden muss (Lieferenergiebedarf).

f$_{GEE}$: Der **Gesamtenergieeffizienz-Faktor** ist der Quotient aus dem Endenergiebedarf und einem Referenz-Endenergiebedarf (Anforderung 2007).

PEB: Der **Primärenergiebedarf** ist der Endenergiebedarf einschließlich der Verluste in allen Vorketten. Der Primärenergiebedarf weist einen erneuerbaren (PEB$_{ern.}$) und einen nicht erneuerbaren (PEB$_{n.ern.}$) Anteil auf.

CO_2: Gesamte den Endenergiebedarf zuzurechnende **Kohlendioxidemissionen**, einschließlich jener für Vorketten.

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Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6
Ausgabe März 2015

GEBÄUDEKENNDATEN

Brutto-Grundfläche	150,42 m²	charakteristische Länge	0,87 m	mittlerer U-Wert	0,150 W/m²K
Bezugsfläche	120,33 m²	Klimaregion	N	LEK T-Wert	15,70
Brutto-Volumen	406,13 m³	Heiztage	220 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	469,07 m²	Heizgradtage	3515 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	1,15 1/m	Norm-Außentemperatur	-14,4 °C	Soll-Innentemperatur	20 °C

ANFORDERUNGEN (Referenzklima) Wohnen

Referenz-Heizwärmebedarf	**erfüllt**	54,40 kWh/m²a	≥	$HWB_{Ref,RK}$	38,30 kWh/m²a
Heizwärmebedarf				HWB_{RK}	38,30 kWh/m²a
End-/Lieferenergiebedarf	ohne Anforderungen			E/LEB_{RK}	111,30 kWh/m²a
Gesamtenergieeffizienz-Faktor	**erfüllt** (alternativ zu $EEB_{max,RK}$)	0,850	≥	f_{GEE}	0,767
Erneuerbarer Anteil	**erfüllt**				

WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	6.135 kWh/a	$HWB_{Ref,SK}$	40,79	kWh/m²a
Heizwärmebedarf	5.864 kWh/a	HWB_{SK}	38,98	kWh/m²a
Warmwasserwärmebedarf	1.921 kWh/a	WWWB	12,78	kWh/m²a
Heizenergiebedarf	14.776 kWh/a	HEB_{SK}	98,23	kWh/m²a
Energieaufwandszahl Heizen		$e_{AWZ,H}$	1,90	
Haushaltsstrombedarf	2.471 kWh/a	HHSB	16,43	kWh/m²a
Endenergiebedarf	17.247 kWh/a	EEB_{SK}	114,66	kWh/m²a
Primärenergiebedarf	22.136 kWh/a	PEB_{SK}	147,16	kWh/m²a
Primärenergiebedarf nicht erneuerbar	20.576 kWh/a	$PEB_{n.ern.,SK}$	136,79	kWh/m²a
Primärenergiebedarf erneuerbar	1.560 kWh/a	$PEB_{ern.,SK}$	10,37	kWh/m²a
Kohlendioxidemissionen (optional)	4.176 kg/a	$CO2_{SK}$	27,76	kg/m²a
Gesamtenergieeffizienz-Faktor		f_{GEE}	0,759	
Photovoltaik-Export	0 kWh/a	$PV_{Export,SK}$	0,00	kWh/m²a

ERSTELLT

GWR-Zahl			ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	21.02.2020	Unterschrift	
Gültigkeitsdatum	20.02.2030		

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten unterschiedlicher Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von der hier angegebenen abweichen.

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Brutto-Grundfläche und Brutto-Volumen

		BGF [m²]	V [m³]
Wohnen	beheizt	150,42	406,13

Wohnen

beheizt

	Formel	Höhe [m]	BGF [m²]	V [m³]
Ground floor				
Ground floor	1 x 150,42	2,70	150,42	406,13
Summe Wohnen			**150,42**	**406,13**

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Bauteilflächen

Scenario C - Alle Gebäudeteile/Zonen

		m²
Flächen der thermischen Gebäudehülle		**469,07**
Opake Flächen	95,96 %	450,11
Fensterflächen	4,04 %	18,96
Wärmefluss nach oben		150,42
Wärmefluss nach unten		150,42

Flächen der thermischen Gebäudehülle

Wohnen — Einfamilienhäuser

				m²
Ceiling to ground 01 - tiles				**46,52**
Fläche	H	x+y	1 x 46,52	46,52
Ceiling to ground 02 - linoleum				**33,76**
Fläche	H	x+y	1 x 33,76	33,76
Ceiling to ground 03 - carpet				**45,85**
Fläche	H	x+y	1 x 45,85	45,85
Ceiling to ground 04 - laminate				**24,29**
Fläche	H	x+y	1 x 24,29	24,29
Ceiling to unheated attic				**150,42**
Fläche	H	x+y	1 x 150,42	150,42
Entrance door (incl window)	W		**1 x 2,40**	**2,40**
Exterior wall 01				**149,27**
Fläche	N		1 x 11,41 * 3,30	37,65
Window 01 (big)			-3 x 1,60	-4,80
Fläche	O		1 x 14,08 * 3,30	46,46
Window 02 (small)			-2 x 0,28	-0,56
Window 01 (big)			-1 x 1,60	-1,60
Fläche	S		1 x 11,41 * 3,30	37,65
Window 01 (big)			-4 x 1,60	-6,40
Fläche	W		1 x 14,08 * 3,30	46,46
Window 01 (big)			-2 x 1,60	-3,20
Entrance door (incl window)			-1 x 2,40	-2,40

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			m²
Window 01 (big)	N	**3 x 1,60**	**4,80**
			m²
Window 01 (big)	O	**1 x 1,60**	**1,60**
			m²
Window 01 (big)	S	**4 x 1,60**	**6,40**
			m²
Window 01 (big)	W	**2 x 1,60**	**3,20**
			m²
Window 02 (small)	O	**2 x 0,28**	**0,56**

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Ergebnisdarstellung

Scenario C

Berechnungsgrundlagen

Wärmeschutz	U-Wert	EN ISO 6946:2003-10, EN ISO 10077-1:2006-12
Dampfdiffusion	Bewertung	ON B 8110-2: 2003
Schallschutz	R_w	ON B 8115-4: 2003
	$L'_{nT,w}$	ON B 8115-4: 2003
	$D_{nT,w}$	ON B 8115-4: 2003

Opake Bauteile

Erforderliche Werte werden in Klammer angeführt

Nummer	Bezeichnung	U-Wert W/m²K		Dampf-diffusion	R_w dB		$L'_{nT,w}$ dB
	Exterior wall 01	**0,095**	*(0,35)*	**OK**	**63**	*(43)*	
	Ceiling to unheated attic	**0,117**	*(0,20)*	**OK**		*(42)*	*(53)*
	Roof	**0,793**		**OK**			
	Ceiling to ground 01 - tiles	**0,132**	*(0,40)*	**OK**			
	Ceiling to ground 02 - linoleum	**0,131**	*(0,40)*	**OK**			
	Ceiling to ground 03 - carpet	**0,130**	*(0,40)*	**OK**			
	Ceiling to ground 04 - laminate	**0,131**	*(0,40)*	**OK**			
	Interior wall 01 - 25	**1,742**		**OK**	**61**		
	Interior wall 02 - 10	**2,433**		**OK**	**50**		

Transparente Bauteile

Erforderliche Werte werden in Klammer angeführt

Nummer	Bezeichnung	U-Wert W/m²K		$U\text{-}Wert_{PNM}$ W/m²K	R_w (C; C_{tr}) dB	
	Window 01 (big)	**0,980**	*(1,40)*		**0 (-; -)**	*(28 (-; -))*
	Window 02 (small)	**1,170**	*(1,40)*		**0 (-; -)**	*(28 (-; -))*
	Entrance door (incl window)	**0,990**	*(1,40)*		**0 (-; -)**	*(28 (-; -))*

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