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## Evaluation of Building Information Modelling to Energy Performance Certificate Workflows: A Variant Study of an Industrial Building

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## Kurzfassung

Diese Diplomarbeit befasst sich mit dem Thema der zunehmenden Digitalisierung im Bereich Building Information Modelling (BIM) im Bauwesen. Im Speziellen liegt der Fokus auf der Optimierung der Energieperformance mit digitalen Werkzeugen. Dabei wurde ein sogenannter BIM zu EPC Prozess (Building Information Modelling zu Energy Performance Certificate) untersucht. Anhand einer Variantenstudie basierend auf Workflows von einer BIM Software zu zwei Energieperformance-Programmen wird nicht nur die Energieeffizienz mit unterschiedlichen Fassadensystemen analysiert, sondern auch der Arbeitsaufwand sowie der Datenverlust.

Beim Referenzobjekt handelt es sich um ein Gebäude mit zwei Zonen – Büro und Industrie. Zum einen kommt ein bereits etablierter Workflow zur Anwendung, welcher mit einem BIM Modell in *ArchiCAD 22* (von *Graphisoft*) mit dem Detaillierungsgrad 300 startet und nach *ArchiPHYSIK 17.0.34* (von *A-Null Development GmbH*) transferiert wird. Zum anderen wird dasselbe *ArchiCAD 22 Modell* in die neue Datenplattform *SIMULTAN* übertragen, welche derzeit an der Technischen Universität Wien (Institut E207) entwickelt wird. Mit beiden Softwares werden Energieausweise erzeugen.

Die Workflows und deren abweichende Ergebnisse der Energieperformance-Programme werden mit den Daten (z.B. Geometrie) des Ausgangsmodells, der auftretenden Datenverluste, des Arbeitsaufwands und Simulationsmöglichkeiten in Relation gesetzt. Daraufhin werden optimierte semi-automatisierte Workflows und Leitfäden empfohlen, um die fehlerhafte Interoperabilität beim Transfer eines BIM-Modells zu Energie-Performance Programmen bestmöglich zu vermeiden.

Des Weiteren wird die daraus resultierende Variantenstudie analysiert und die mögliche Anwendung von Energieausweisen zur Optimierung der Gebäudeperformance in der frühen Entwurfsphase thematisiert. Um diesen Aspekt im Zuge dieser Diplomarbeit näher erläutern zu können, werden pro Programm drei Energieausweise mit unterschiedlichen Bauteilaufbauten generiert und gegenübergestellt. Diese Berechnungen werden mit benutzerdefinierten, standardmäßigen und hochwertigen Bauteilaufbauten vorgenommen. Üblicherweise werden Energieausweise kurz vor der Baueinreichung erstellt. Allerdings sollten Architekturschaffenden auch wichtige Energiekennzahlen bereits in der frühen Entwurfsphase beachten, um die Energieeffizienz und den Gebrauch von umweltschonenden Materialien positiv zu beeinflussen. Durch die Energieausweise ist visuell feststellbar, welche Fassadensystemwahl unter diversen energietechnischen Aspekten von Vorteil oder Nachteil ist. Dadurch kann eine energieeffiziente Bauweise und Gebäudetechnik bereits in der frühen Entwurfsphase gefördert werden.

## Abstract

This master thesis addresses the increasing digitalisation in the field of Building Information Modelling (BIM) in the construction sector. The particular focus is on improving the energy performance (EP) by means of digital tools. Therefore, a so-called BIM to EPC process (Building Information Modelling to Energy Performance Certificate) was evaluated. By testing the workflows from one BIM Software to two Energy Performance Tools, a variant study with three different facade systems was generated. Not only the energy efficiency could be analysed, but as well the workload and data loss.

The reference object is a building consisting of two conditioned zones – an office and an industry area. The first workflow is already well established in the building industry and starts with a detailed BIM model (LoD 300) in *ArchiCAD 22* (by *Graphisoft*) that is imported to *ArchiPHYSIK 17.0.34* (by *A-Null Development GmbH*). The second workflow transfers the same *ArchiCAD 22* model to the new data platform *SIMULTAN*, which is currently developed at the Vienna University of Technology (Institute E207). In both tools Energy Performance Certificates are generated.

The workflows and their diverging data of the EPC software are compared to the data of the reference object, the occurring data loss, the amount of work, as well as further simulation possibilities. Resultant improved workflows and guidelines are suggested to avoid interoperability issues while transferring a BIM model to EP Tools.

Furthermore, the variant study is analysed and the possible use of EPCs for improving the building performance in the early design phase are discussed. To clarify this aspect more closely within the thesis, three EPCs with different facade systems are generated in each EP Tool and subsequently compared. The simulations are calculated with customised, standard, and high-end facade systems. Usually, EPCs are created shortly before the submission. Though, architects should be aware of relevant energy values to positively influence the energy efficiency and the use of eco-friendly materials already in the early design phase. Due to energy simulations, it is possible to visualise advantages and disadvantages by using certain facade systems. Therefore, energy-efficient constructions as well as building services can be supported in the early design stage.

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## Abbreviations

BIM	Building Information Modelling
CO <sub>2</sub>	Location-Based Carbon Dioxide Emissions in German CO <sub>2SK</sub> – standortbezogene Treibhausgasemissionen
PED	Location-Based Primary Energy Demand in German PEB <sub>SK</sub> – standortbezogener Primärenergiebedarf
AECO	Architecture, Engineer, Construction and Operation
BEM	Building Energy Modelling
CAD	Computer Aided Design
EED	Location-Based End Energy Demand in German EEB <sub>SK</sub> – Endenergiebedarf
EP	Energy Performance
EPC	Energy Performance Certificate
EPC A.C.	EPC generated in ArchiPHYSIK - Customised Facade Systems
EPC A.S.	EPC generated in ArchiPHYSIK - Standard Facade Systems
EPC A.H.	EPC generated in ArchiPHYSIK - High-End Facade Systems
EPC S.C.	EPC generated in SIMULTAN - Customised Facade Systems
EPC S.S.	EPC generated in SIMULTAN - Standard Facade Systems
EPC S.H.	EPC generated in SIMULTAN - High-End Facade Systems
EP Tool	Energy Performance Tool
f	Total Energy Efficiency Factor in German f <sub>GEE</sub> – Gesamtenergieeffizienz-Faktor
gbXML	Green Building Extensible Markup Language
HED	Location-Based Heating Energy Demand in German HWB <sub>REF,SK</sub> - standortbezogener Heizwärmebedarf
HVAC	Heating, Ventilation, Air-Conditioning
IFC	Industrial Foundation Class
LCA	Life Cycle Assessment
LoD	Level of Detail
OBJ	Object Format
TU Wien	Vienna University of Technology
UI	Userinterface

# 1. Introduction

The construction industry produces 50 % of the worldwide CO<sub>2</sub> emissions (Röck, et al., 2018), as well as the estimated consumption of 30-35% of global energy and 25% of global water (Zaid, et al., 2020). For this reason, it is more important than ever to build energy-efficient buildings. To reach the best possible result, the facilities need to be intensely thought through from inception to operation, and additionally supported by simulations, analyses, evaluations, adaptations, and improvements already in the early design stage (Habibi, 2017; Zimmerman & Eng, 2006; Saieg, et al., 2018).

In this process, various Building Information Modelling (BIM) software become more prevalent to draw models, and to store detailed information within parameters and a big amount of other data (National BIM Standard US, 2015). These BIM tools enable the possibility to change materials of the model elements as well as their dimensions in a very short time, in order to obtain variations and different simulations of the model (BIMpedia - Plandata GmbH, 2021; Autodesk, 2021). To create an energy performance simulation, the data of a 3D BIM model is transferred to a Building Energy Modelling (BEM) tool. In this way, it is possible to verify a suitable facade system to provide an excellent energy efficiency of a building. In the early design stage, examining such variants can be a very useful decision support system for architects and their clients (Habibi, 2017; Zhu, 2014; Gao, et al., 2019; Gourlis & Kovacic, 2017).

According to the *Austrian* LM.VM. 2014 (Lechner, 2014) architects are officially qualified to create Energy Performance Certificates of buildings. But usually, an EPC is generated shortly before submission by a building physicist, at a time when all important building performance decisions have already been made (Bogenstätter, 2000).

It needs to be considered that problems occur while transferring 3D models from BIM to EPC Software using an open-data format. The most common issues are data loss, problems with interface communication and the interoperability of multiple software (Gourlis & Kovacic, 2017). A lot of workflows require pre- and post-processing to obtain the right results, just like *ArchiCAD* to *ArchiPHYSIK*, *Revit* to *ArchiPHYSIK*, *ALLPLAN* to *ArchiPHYSIK* (Reisinger, et al., 2019).

This leads to the question: What does a suitable BIM to EPC workflow look like that is also able to easily create variants for supporting decision making at early design stage? Furthermore, what impact do various facade systems have on the overall energy performance of an industrial building?



## 2. Research Objective

The main research objective of this thesis is to improve the design process for energy-efficient buildings supported by digital tools.

The first sub-aim of this thesis is the evaluation and comparison of two BIM to EPC workflows. Both examined workflows start with an already designed BIM Model LoD300 (*ArchiCAD*) which is then transferred to two different Energy Performance (EP) Tools (*ArchiPHYSIK* and *SIMULTAN*). The first examined workflow, *ArchiCAD* to *ArchiPHYSIK* (A), is already well-established in current design practice in Austria. The second examined workflow, *ArchiCAD* to *SIMULTAN* (S), is a novel workflow, whereby *SIMULTAN* is still being developed at the Vienna University of Technology. Based on the evaluated workflow results two improved workflows are developed and a guideline is provided to enhance the user-friendliness and interoperability of the BIM to EPC workflows.

The second sub-aim is the impact assessment of three different facade systems to the overall energy performance of an industrial building. Thereby, investigating the impact of a customised (C), a standard (S), and a high-end (H) facade system within a variant study. The customised facade system is used for the evaluation of both BIM to EPC workflows (EPC A.C. and EPC S.C). The standard facade system is applied on the two improved workflows (EPC A.S. and EPC S.S.). Finally, to test the compatibility of the examined EP Tools for early variant studies and to assess the impact of varying materials the standard facade system is replaced by a high-end facade system (EPC A.H. and EPC S.H.). The obtained EPC results of the variant study are then compared and discussed.



Figure 1: Research Objectives of this Master Thesis. Testing workflows with a customised facade system (EPC A.C. and EPC S.C.). Improving workflows with a standard facade system (EPC A.S. and EPC S.S.). Replacement of standard facade system by high-end facade system (EPC A.H. and EPC S.H.)

## 3. State of The Art

### 3.1. Building Information Model / Modelling

In 1974, Chuck Eastman et al. already presented a vision of digitally described buildings in the project of the Building Description System to visualise and analyse them. Due to this work, he defined the path for the current Building Information Model – shortly called BIM (Eastman, et al., 1974). The expression BIM sometimes leads to confusion caused by the multiple existing definitions. The four common distinctions of BIM’s expression are: The Building Information Model as a product - the model itself. Building Information Modelling can be defined as a software, paradigm, or process. According to the NBIM Standard US (2015) the Building Information Model is a parametric intelligent digital building which is object-oriented and contains a large amount of data. BIMpedia (2021) put the definition into a formula:

$$\text{BIM} = (3\text{D} + \sum_i \text{t} + \text{I}) * \text{n}$$

Therefore, the Building Information Models consists of a given number of 3D elements to which a certain amount of information per life cycle phase (t) is attributed and which holds a programmed intelligence (I) (BIMpedia - Plandata GmbH, 2021).

The BIM-software is capable of interacting with non-CAD-based tools, just as quantity surveyors or project management tools (BIMpedia - Plandata GmbH, 2021). Van Berlo and Sebastian (2010) also stated that BIM is a suitable tool for facilitating communication as well as for the exchange of information between planners, engineers, and other stakeholders. BIM defined as a new paradigm is “an emerging technological and procedural shift in the architecture, engineering, construction, and operations (AECO) industry” (Succar, 2009). Contrary to that, Penttilä (2006) sees Building Information Modelling as a process that includes managing a physical building in its design and its digital project data throughout the whole facility’s life cycle. The process is also a technology that provides efficient and effective projects from early design stage to operation (Volk, et al., 2014). According to von Both (2011) BIM “is a collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets” (UK Government & Crown, 2012).

Moreover, according to the British Standards 1192-4 (2014), BIM as a process can be divided into four different levels. Level 0 is the unmanaged CAD that exchanges data with 2D physical paper or digital paper without following common standards and processes. Level 1 is handling 2D as well as 3D format with collaboration tools for digital data exchange. Level 2 manages BIM tools - 3D environment – and represents a collaborative way of working by transferring BIM data within suitable file formats to

different stakeholders who use their own CAD tools and models – currently this is the most common way. Level 3 is the integrated BIM that allows open access (open-Data) and integration of information via IFC or COBie format. This level also stands for launching a project framework to ensure consistency, preventing confusion, and supporting an interdisciplinary BIM-based work environment (National BIM Standard, 2021; British Standard Institution, 2014).

BIM addresses the design tool and the process of data exchange. Therefore, the feature of delivering different BIM data to simulation and analysis tools is essential - geometrical as well as non-geometrical attributes (Gourlis & Kovacic, 2017). The data format gbXML (green building extensible markup language) by Autodesk was developed for an energy simulation application and is suitable to transfer data to other analysis tools, just as Energy Performance Tools. GbXML is simple to understand and easy to be implemented by other software developers (Dong, et al., 2007; Bahar, et al., 2013). Another data-format is Industry Foundation Classes (IFC) developed by *buildingSMART*. IFC can hold a wide range of information, works with open non-proprietary interfaces, interacts between different programmes and is therefore suitable for open-BIM (*buildingSMART*, 2020). Unfortunately, the IFC format shows bad interoperability or is even unsuitable for BIM software. This interoperability issue is caused by companies who create different software that translates IFC in a slightly different way (Gourlis & Kovacic, 2017). For example, the well-established software developer company Autodesk provides a so-called closed-BIM solution. They developed their own data-server – BIM 360 – and connected it to different Autodesk software which are already used in the architecture, engineering, construction, and operation industry. In this way the interoperability works with hardly any data loss (Autodesk, 2021).

Nevertheless, there is a lot of pressure in the AECO industry on BIM for designing, planning, and in general managing the whole life cycle of buildings with all stakeholders, planners, and engineers. For example, this is exactly what the UK Government Construction Strategy is intending to do. (The Infrastructure and Projects Authority, 2016).

### 3.2. Building Information Model to Building Energy Model – Interoperability Process

As well as BIM, the expression BEM – Building Energy Modelling, can be defined as a product (the model) when talking about a Building Energy Model. Or Building Energy Modelling as a powerful digital method to study the performance of facilities and analyse the architectural mechanical design (United States General Services Administration, 2015). Based on these Building Energy Performance Simulations, it is possible to calculate peak loads and base further decisions like the plant size on these results (Pinheiro, et al., 2018). According to Habibi (2017) Energy Performance is a “systematic

approach to evaluate the external and indoor conditions, as well as cost factors”. Further, these results describe criteria that can improve the building’s performance, make it sustainable and reduce carbon dioxide emissions which are calculated via the energy performance and the primary energy consumption of a building at a specific location and building structure (Habibi, 2017). By reconsidering the results of simulations, the building can be improved. Unfortunately, however, energy performance simulations are hardly ever calculated in the early design stage when the design is determined and decisions are made, as many researchers state (Habibi, 2017; Zhu, 2014; Gao, et al., 2019; Gourlis & Kovacic, 2017). Gao et al. (2019) goes even further and states BEPS should be used throughout the whole design process to coordinate all decisions to create an optimised building.

The BIM to BEM interoperability process expects a data-transfer within a closed- or open-BIM process. An example for closed BIM to BEM interoperability process is BIM-360 by Autodesk, as already mentioned. This server holds one model that all planners and engineers can edit with their discipline-specific software. (Autodesk, 2021) Unfortunately, the current open BIM to BEM interoperability process causes data loss and other interoperability problems with the geometry – especially non-planar – and attached information (Kovacic, et al., 2013; Maile, et al., 2013; Nasyrov, et al., 2014).

Bazjanac and Kiviniemi (2007) state that the Building Information Model contains much more data compared to Building Energy Model. These realistic BIM visualisations are modelled in a very high Level of Detail (LoD) and unfortunately fail to be transferred to an Energy Performance Tool (Prada-Hernández, et al., 2015). The architectural BIM model includes, for example, room stamps to describe a room in m<sup>2</sup>. But this level is already too detailed because BEM rooms identify separate thermal zones (Georgescu & Mezić, 2015; Kensek & Noble, 2014; Reisinger, et al., 2019). For this reason, the BIM model needs to be simplified. The geometrical representation is pre-processed before it can be transferred to Building Energy Tool (Reisinger, et al., 2019). The required LoD for a model for the BIM to BEM interoperability process is as minimalistic as those in the very early design stage. But the BIM model, which is as much simplified has no purpose as an architectural model anymore (Reisinger, et al., 2019). After the import to the Energy Performance Tool, the planner needs to edit the transferred data and add information manually as well (Pinheiro et al, 2018). This way of BIM to BEM works only one-way, the other way around is not possible (Gourlis & Kovacic, 2017).

However, architectural models can be modelled in BIM programs with special layer combination to facilitate the BIM to BEM interoperability process without wasting too much time on pre-processing and without making the model useless for architectural purpose. Unfortunately, the knowledge of modelling in a suitable way for BIM to BEM is not common in architectural offices (Gourlis & Kovacic, 2017; Azhar, et al., 2011; Maile, et al., 2013). In addition to this, Ahn et al. (2014) state that BEM tools

are difficult to use for architects and engineers, due to the little knowledge of simulations, even when they have user-friendly interfaces.

Furthermore, the focus of analysing and optimising the energy performance of buildings was on domestic buildings (De Boeck, et al., 2012; Chanel, et al., 2016) and marginally on offices and educational institutions (Ruparathna, et al., 2016). However, recently there are more proposals that include research on the energy performance improvement of industrial buildings as well (Bleicher, et al., 2014). According to Gourlis and Kovacic (2017) this is attributable to the very short lifetime of industrial buildings, which is a category of buildings that needs to provide flexibility, not only on the utilisation of the facility, but also on the energy analysis and its performance to find the optimal solution along the life cycle.

Nevertheless, BEM has the possibility to save money and time, create sustainable buildings, and optimise their energy performance due to simulations, especially when they are evaluated in the early design stage when designer's decisions still can be influenced (Gao, et al., 2019).

### 3.3. Energy Performance Certificate in Austria

According to OIB RL 6 (OIB RL 6, 2019) the Energy Performance Certificates (EPC) describes the total energy use of a building at a certain location. The steady monthly balance method is the conventional method to calculate an EPC according to ÖNORM B 8110-6:2019-03-15 (Austrian Standards International - Standardisierung und Innovation, 2021). This method reveals the average energy use for each month and is the official one for submissions. EPCs can be created by dynamic methods as well, which are more precise but demand more detailed information input. In this way, the energy consumption for each minute or hour over a certain period can be simulated. Of course, simulations are no guarantee for the real overall energy use since the utilisation always depends on users' behaviour (ÖNORM B 8110-6, 2019).

Since 2009, the conventional EPC is mandatory for building submissions (new construction and renovation), submission of funding, for selling or renting buildings in Austria. These include the following facility categories: domestic buildings (one or two, three until nine, ten or more), offices, educational institution, hospitals, nursing homes, hotels, restaurants, event locations and multipurpose buildings, sports complex, salesrooms, and other conditioned constructions. For these categories' utilisation profiles are provided for the calculations and can be found in ÖNORM B 8110-6:2019-03-15 (Austrian Standards International - Standardisierung und Innovation, 2021). The finished EPC consists

of two precisely defined pages and attachments that include the standards, used authorised simplification methods, geometrical information, building services and facade systems.

In Austria the EPC is defining the total energy efficiency of a building by the following four values:

- $HED_{REF, LB}$  – location-based Heating Demand [kWh/m<sup>2</sup>a]  
in German  $HWB_{REF, SK}$  – standortbezogener Heizwärmebedarf
- $PED_{LB}$  – location-based Primary Energy Demand [kWh/m<sup>2</sup>a]  
in German  $PEB_{SK}$  – standortbezogener Primärenergiebedarf
- $CO2_{LB}$  – location-based Carbon Dioxide Emissions [kg/m<sup>2</sup>a]  
in German  $CO2_{SK}$  – standortbezogene Treibhausgasemissionen
- $f_{TEE}$  – total energy efficiency factor [-]  
in German  $f_{GEE}$  – Gesamtenergieeffizienz-Faktor
- $EED_{LB}$  – location-based End Energy Demand [kWh/m<sup>2</sup>a]  
in German  $EEB$  – Endenergiebedarf

*In this thesis all abbreviations of location-based and the total energy efficiency are neglected. The names are described as: HED, PED, CO2, f, EED.*

Of course, there are other values as well in the EPC, but these are the most representative ones. The results of the first four values describe certain energy efficiency categories, which are displayed in the following *Table 1* (OIB RL 6, 2019, p. 10).

Klasse	$HWB_{Ref, SK}$ [kWh/m <sup>2</sup> a]	$PEB_{SK}$ [kWh/m <sup>2</sup> a]	$CO2_{SK}$ [kg/m <sup>2</sup> a]	$f_{GEE}$ [-]
A++	10	60	8	0,55
A+	15	70	10	0,70
A	25	80	15	0,85
B	50	160	30	1,00
C	100	220	40	1,75
D	150	280	50	2,50
E	200	340	60	3,25
F	250	400	70	4,00
G	> 250	> 400	> 70	> 4,00

*Table 1: Categories of the Total Energy Efficiency of buildings according to OIB RL 6 2019 and previous versions, including the required values of HED, PED, CO2 and f. (OIB RL 6, 2019, p. 10)*

Several licensed Energy Performance Tools can be used to create these certificates such as:

- |                                       |  |
|---------------------------------------|--|
| ArchiPHYSIK                           | by A-Null Development GmbH   |
| Gebäudeprofi 3D & Gebäudeprofi Dua 3D | by ETU GmbH  |
| ECOTECH                               | by BuildDesk Österreich GesmbH   |
| GEQ                                   | by Zehentmayer Software GmbH   |
| AX300                                 | by EDV Software-Service GmbH & Co<br>(Arge Stiba Holding Schulungs GmbH, 2020) |

Those tools are directly based on several standards that are valid in the European Union and in Austria only, like EU Directive 2002/92/EC, OIB Richtlinie 6:2019, OIB Richtlinie 3:2019, ÖNORM B8110-1-6, ÖNORM H5055, and several other ÖNORM. The Austrian Institute of Construction Engineering (OIB) is responsible for the OIB standards. Nevertheless, to create a valid EPC, it is mandatory for the user to have the required permission for this, like an architect, civil engineer or building physics engineer (Lechner, 2014).

### 3.4. ArchiPHYSIK

The software *ArchiPHYSIK* by the company *A-Null Development GmbH* was published 25 years ago. The latest version is *ArchiPHYSIK 17* and was released in spring 2020, which was used for this thesis. It is a building physics software and specialised on energy performance analysis. *ArchiPHYSIK* is authorised by the Austrian regulative. The analyses and simulations are focused on energy performance, overheating, ecology, sound insulation, moisture protection and CAD data transfer. *ArchiPHYSIK* can be used for new buildings, renovations, and existing buildings. The tool also provides the EPC standards of 2008, 2011, 2012, 2015, 2019 and even the European Standards. It can be used for one and multiple zones buildings. The calculations are simplified, yet still accurate, default values can be set and adapted for building usages. These utilisations include domestic buildings (one or two, three until nine, ten or more), offices, educational institution, hospitals, nursing homes, guest houses, hostels and hotels, restaurants, event locations and multipurpose buildings, sports complex, indoor swimming pools, salesrooms, and other individual conditioned constructions (A-NULL Development GmbH, 2021). The default values can also be found in ÖNORM B 8110-6:2019-03-15 (Austrian Standards International - Standardisierung und Innovation, 2021). According to the *A-Null Development GmbH* the software uses calculation methods from the following authorised standards:

Facade Systems	ON B 8110-6:2019-01-15
Windows	EN ISO 10077-1:2018-02-01
Heating Technology	ON H 5056-1:2019-01-15
Ventilation Technology	ON H 5057-1:2019-01-15
Cooling Technology	ON H 5058-1:2019-01-15
Lighting	ON H 5059-1:2019-01-15
Unconditioned Elements	Simplified ON B 8110-6:2019-01-15
Underground Elements	Simplified ON B 8110-6:2019-01-15
Thermal Bridge	Blanket ON B 8110-6:2019-01-15
Shading	Simplified ON B 8110-6:2019-01-15
Climate Model and Utilisation Profiles	ON B 8110-5:2019-03-15
Total Energy Efficiency	ON H 5050-1:2019-01-15 & ON H 5050-2:2019-11-01
Heating Energy Requirement	ON H 5056-1:2019-01-15 & ON H 5056-2:2019-11-01

Table 2: *ArchiPHYSIK* calculates with the latest versions of the Austrian Standards. Previous versions are available as well.

When creating a new project, the user can decide either to use a template or start with a plane project. No matter which one is chosen, there are standard construction elements that can be added to the project via the data assistant. This function allows the user to create new constructions or change the template constructions. The programme automatically calculates the U-Value, risk of moisture and noise insulation of the construction element. This feature can be found in one of the headers, where also other information like the planner, constructor, address (also for geoinformation), and data about the heating, ventilation, air conditioning and cooling systems for the building needs to be added. The user can create a geometry in a table in the programme or import it via Add-On that needs to be installed in other software. This Add-On is provided for only two software so far, *ArchiCAD* by *Graphisoft* and in *SketchUp* by *Trimble*. In both tools APS-files are created. When importing them to *ArchiPHYSIK*, the construction elements can either be set as new ones or be connected to existing ones. However, the data transfer cannot transport BIM-data like the IFC-data format, which makes it impossible after the import to have a 3D model in the Energy Performance Tool. Manually adding, adapting, and deleting elements is still possible after the import. (A-NULL Development GmbH, 2021)

### 3.5. SIMULTAN

*SIMULTAN* is a project that was initiated in 2013 and is currently developed at the Institute of Material Technology, Buildings Physics and Building Ecology at the Vienna University of Technology. The initial purpose of *SIMULTAN* was to develop a decision-making tool to support simultaneous, flexible and multidisciplinary planning. The outcome was a proof-of-concept of a Big-Open-Real-BIM Data Model to improve the workflow between stakeholders, planners, and engineers. In 2017, the focus on analysing networks was realised by the implementation of a network calculation tool. This application visualises the electrical and cooling infrastructure in the 3D model and supports the dynamic simulation of energy demand of buildings and building complexes as well. One of the visions of *SIMULTAN* is to visualise the whole life cycle of a building, from the early design stage through construction, operation, renovation, changing the utilisation, demolition, and recycling. The result of a *SIMULTAN* project is an appropriately detailed and flexible digital model of a real building – or in the future even a digital twin. At present, the developers also work on features to export data from *SIMULTAN* to various tools and applications with a minimum of users' effort and without any data loss. (Bednar, et al., 2018)

Data protection is assured by different users for each project. All users have their very own account to access a certain project and can only see or edit data which they are authorized to. To ensure more safety, all accounts are protected by usernames and passwords. New accounts with different



maintenance permissions for elements depending on the field of competence can be added in the user management settings. A user's role can be set as administrator, architect, building contractor, building developer, building operator, building physicist, building service engineer, energy network operator, energy supplier, fire safety specialist, guest, moderator, or process measuring controller. These users are able to add information to the project and define its visibility for others. In this way, data can be seen and referenced by others, yet not edited. This IT-environment ensures the avoidance of data loss, double input of information, and different input values for the same parameter. Therefore, the input time can be reduced, a consistent model is available, variants and risks can be analysed and evaluated. (SIMULTAN Wiki, 2021)

The *SIMULTAN* data model is generic and can hold arbitrary data structures defined by other models. Various parts of different models can be combined to a new data model. Compared to IFC, which has more than 600 different types and entity definitions, *SIMULTAN* exists of only a few basic types. By using these basic elements, users can build their own specific data model and define its interaction. Those created hierarchical data structures can differ from the level of detail in the very same project – from low to high detailed level of data, from simple to complex data models. Owing to this fact, it is possible to work almost simultaneously in a team. Already created projects can be used as libraries for materials, construction elements, building service systems, and their component structure etc. (Pascaleva, et al., 2018)

The mentioned few basic elements are components, parameters, value fields, networks, calculations, vertices, edges, surfaces, volumes, projects, users, and resources. There are also support elements which are not visible for users and operate in the background. Users can edit, read, share, and publish components depending on the user's role. A component can contain parameters, calculations, value fields and sub-components. Calculations use parameters of the component or the sub-component as input or output. Each component can be referenced by any other, which allows the reuse of parameters. This is useful when the current user has no maintenance permission for that component. In this way the data model is extraordinary flexible as well. A parameter is either a numerical value or a textual data, which can be filled in manually or is reused from the referenced component that has a parameter with the same name. The parameter can query data from a value field as well. Numerical values can be the result of a calculation and can be the input for other calculations at the same time. A minimum and a maximum value can be set for a parameter to track given requirements. *SIMULTAN* has three types of value fields: a table value field, a 3D value field, and a function value field. The table value fields can be imported from an Excel-Sheet, manually filled in or manually created with a function field. Elementary arithmetic operations and mathematical functions can be used for calculations. Chains of

multiple calculations are possible as well, but calculation loops are not supported. Networks consist of nodes, edges, and sub-networks. They provide a non-linear graph-based data structure for modelling flow in a network, for example, for ventilation systems (SIMULTAN Wiki, 2021).

In addition to the main application, the so-called *Component Builder*, which visualises the data model and its structure, *SIMULTAN* has multiple sub-applications. The *Geometry Viewer* defines a geometrical 3D model whose elements are getting manually assigned to elements of the *Component Builder*. The *Geometry Viewer* uses vertices, edges, faces and volumes to define buildings in a rather minimalistic way. Faces need to be assigned to construction components and volumes to room components. After this step, the construction thickness is visible and affects the net volume of adjacent rooms. In the *Geometry Viewer*, the user can also place and visualise network elements. Furthermore, the geometrical data can be saved as an OBJ file, while the data model itself can be exported in CSV or XML format. Other applications are the network editor to define networks, the value editor to edit tables, 3D value fields and functions fields, and the project explorer to hold all kinds of files (PDF, JPG, PGN, Excel-files, etc.). The latest implemented client is the site planner, another 3D tool which enables the visualisation of huge areas including multiple buildings and maps with their correct GPS coordinates, elevations, and distortions. The Excel-Tool Editor allows the user to create rules for components and parameters to be exported as well as imported from *Excel* (by *Microsoft*). With the Excel-Tool Editor, information of the data model can be exported to Excel-Sheets. The so called "*TopPhiCO2*" Excel-Tool calculates essential energy performance values of a multizone building and is currently being developed by Thomas Bednar at TU Wien (Bednar, 2021 - unpublished). The values are the results of a dynamic simulation method. The conventional steady monthly balance method is actually not included in *TopPhiCo2*. However, to create the conventional EPC as well, a connection to an official EPC Excel-Tool was developed. This is the so-called "*Excel-Validierungs-Tool*", developed by Christian Pöhn (Pöhn, 2016 - unpublished). This *Excel-Validierungs-Tool* was developed in 2016 and therefore operates with the OIB RL 6 version of 2015. The connection automatically fills the calculated data of *TopPhiCO2* into the *Excel-Validierungs-Tool*, which performs its calculations and writes it back to *TopPhiCO2*. New sheets are added automatically which contain EPCs for each conditioned zone (SIMULTAN Wiki, 2021).

Due to the current development of *SIMULTAN*, including all user interfaces and the *TopPhiCO2*-Tool, new versions are published approximately on a weekly basis. Errors that occurred in the process of this master thesis might already be fixed in the current version.

For exactly this reason the author decided to use the latest versions of the effective date 12<sup>th</sup> March 2021: *SIMULTAN* Version: 0.2.104 and *TopPhiCO2* Fassung *SIMULTAN* 90

## 4. Methodology

In order to assess and improve the design process of energy-efficient buildings at early design stages, two BIM to EPC workflows are tested, evaluated and improved in this thesis. The first workflow, *ArchiCAD* to *ArchiPHYSIK* (A), is already well-established in Austrian design practice. The second examined workflow is testing the process from *ArchiCAD* to a novel data platform with implemented EP assessments *SIMULTAN* (S).

The research methodology followed in this thesis is based on a pilot project of an industrial building from the food production sector. For the test and evaluation of the two workflows a variant study is conducted and the impact of three different facade systems on the EPC results is examined. Therefore, the workflow analysis and the obtained EPC results are then compared and discussed. Finally, a conclusion and an outlook for future research activities are given.

The overall methodology of the master thesis is visualised in *Figure 2*.

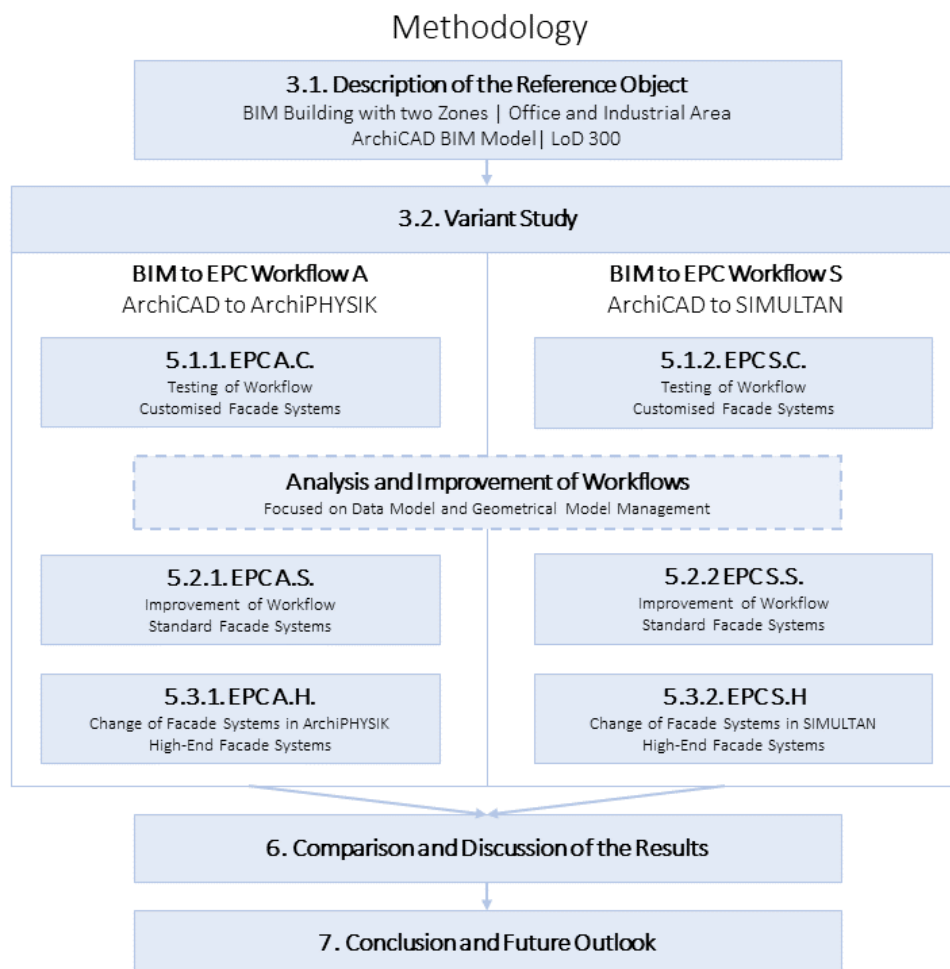


Figure 2: Research Methodology of this Master Thesis

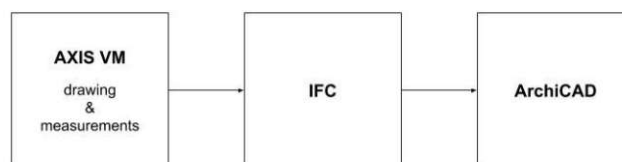
## 4.1. Description of the Reference Object

### *General Design and Project Information: The Bakery “Brot und Spiele”*

The reference object used in this master thesis was developed in the design studio BIM\_bake at the Institute of Integrated Planning and Industrial Production at the Vienna University of Technology in the winter term 2017/2018. The lecturers were Univ.-Prof. Dipl.-Ing. Dr. techn. Iva Kovacic, Dipl.-Ing. Lars Oberwinter, Dipl.-Ing. Julia Reisinger and Mag. Rüdiger Suppin. The project “Brot und Spiele” was designed by an interdisciplinary group of three students: Theresa Dierneder (architecture student), David Nöbauer (civil engineering student) and the author herself Clara Gmeiner (architecture student).

One task of the design studio was testing the interoperability, the interface communication, and the workflow of two different BIM software via open-data format by transferring the architectural model and the structural model. The group decided to use *ArchiCAD* (by *Graphisoft*) for modelling the architectural model and *AxisVM* (by *IngWare AG*) to model the structural model. The open-BIM workflow with RFEM via *Revit* (by *Autodesk*) was tested as well.

One of the key findings the group gained was how important an interdisciplinary teamwork including a lot of communication in the early design stage was. In this way, the group was able to create an architecture design with an appropriate structural concept much faster. In this was a lot of time was saved afterwards, due to minimising pre- and post-processing to transfer the model via IFC format. *AxisVM* is an open-BIM software as well, but the import to *ArchiCAD* and way vice versa worked clearly superior compared to using the software *Revit*. The interoperability is more accurate and post-processing is rarely required. The workflow is visualised in *Figure 3*.



*Figure 3: Workflow of the structural model from AxisVM via IFC-data format to ArchiCAD. The architectural model was then modelled in ArchiCAD.*

### *Description of the Reference Building*

The reference building is an industrial bakery, which is situated in Völs, a suburb of Innsbruck, in Tyrol. The estate site has a size of 50.000 m<sup>2</sup>, is located between fields, close to an airport, a river, train rails as well residential areas and surrounded by the Austrian Alps. The building and its surroundings are visualised in *Figure 4*.



Figure 4: Visualisation of the Building "Brot und Spiele" and the Surroundings

The Bakery consists of two big volumes that are connected by a third volume including an atrium and a yard. The first part of the building contains four floors. The basement contains the changing rooms and a plant room. The ground and the first floor include a foyer, offices, rooms for social interactions, seminar rooms as well as a part of the pastry production area. The second floor is mainly a canteen and a hands-on workshop area, which can also be used as an event location. On the second floor a big terrace and generous seating steps leading down to the ground floor were designed. The second building contains the production, storage, and transportation area. The sloping shape of the roof is a profile imitation of the surrounding Alps. In this way of shaping, the vertical surfaces are used for natural illumination of the production area. These two buildings - office and production area - are connected by an atrium, where the pastry production area is located. The student group decided to use wooden frame constructions for walls, ceilings, and roofs. The walls facing south, some to the east, and some to the north are curtain walls. In Figure 5 to Figure 9 floor plans and sections of the ArchiCAD model are visualised to provide insights and a better understanding of the building.

An industrial bakery has specific requirements for conditions regarding temperature, size, and height of rooms, just like the different conditioned zones of offices, production, storage, and logistic areas. However, this thesis' focus is on testing of workflows from *ArchiCAD* to *ArchiPHYSIK* and from *ArchiCAD* to *SIMULTAN* as well as an included variant study. For this reason, the small temperature zones of the industrial area will be neglected in this thesis. The building will have only two zones - one office area and an industrial area. Furthermore, to keep this master thesis in an appropriate scope of work, the industrial zone is defined by the default values of event locations (according to Austrian OIB RL 6) in the following simulated Energy Performance Certificates.

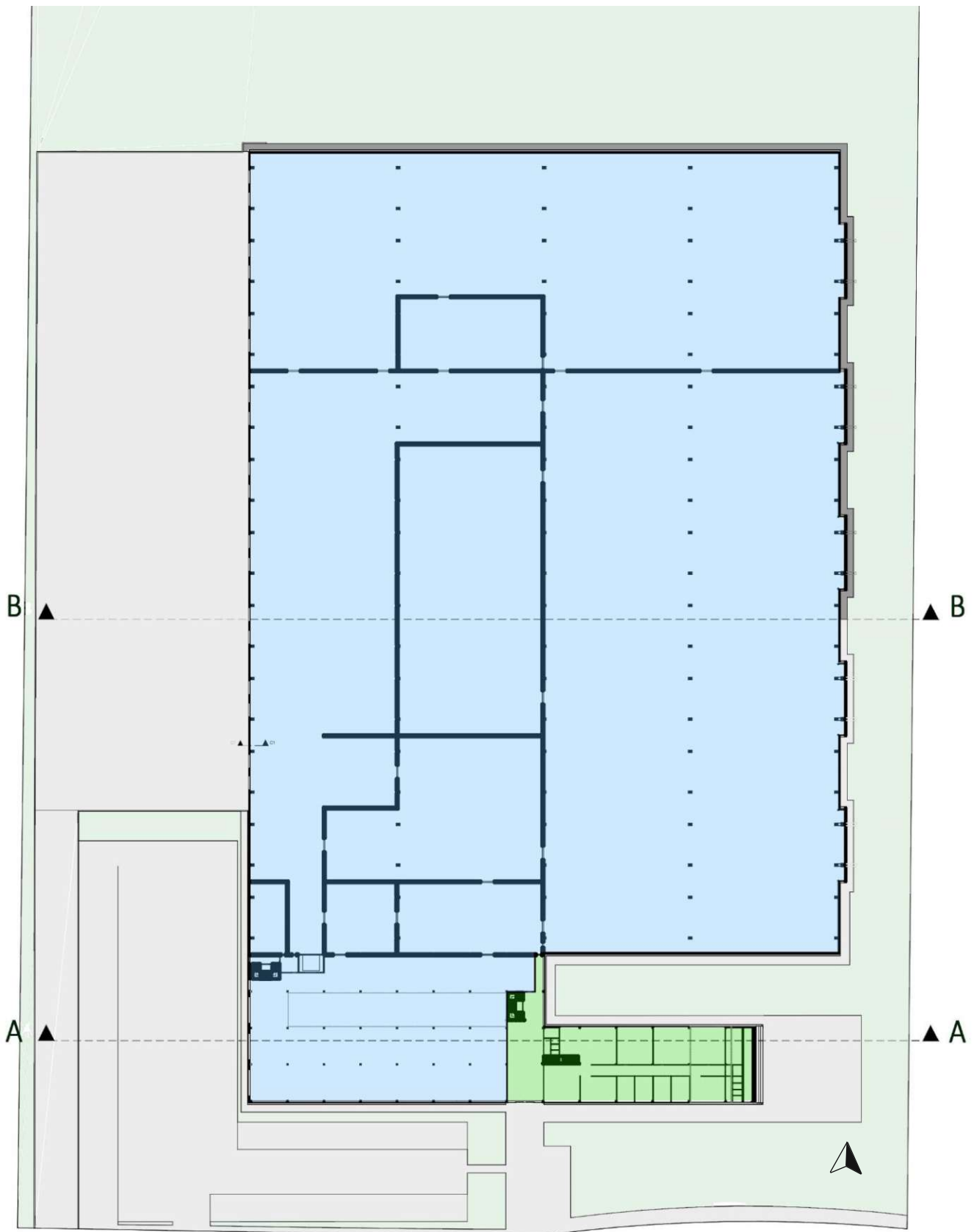


Figure 5: M 1:1000 Ground Floor (Industrial Area – Blue, Office Area – Green)

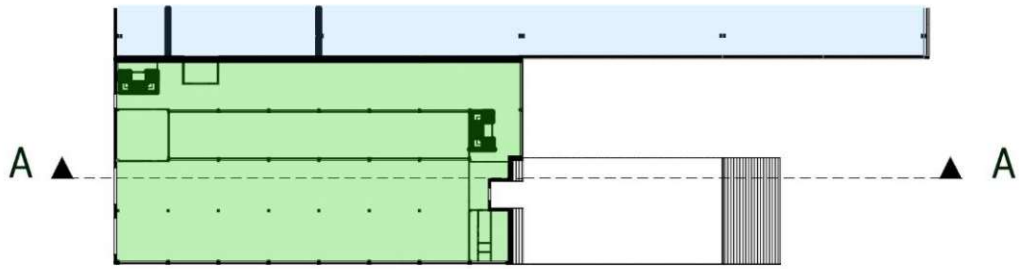


Figure 6: M 1:1000 Second Floor (Industrial Area – Blue, Office Area – Green)

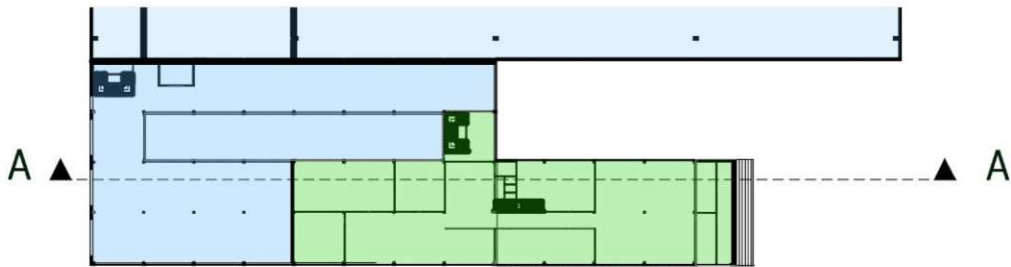


Figure 7: M 1:1000 First Floor (Industrial Area – Blue, Office Area – Green)

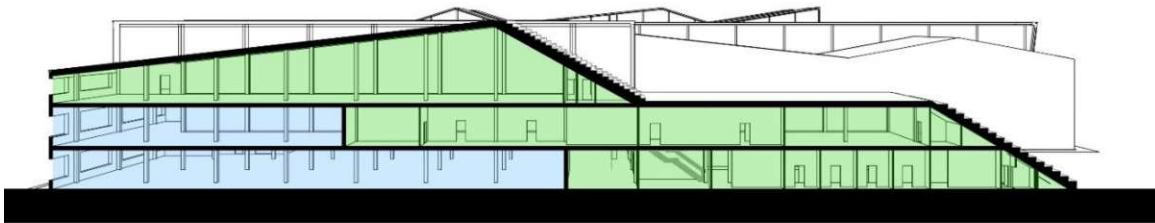


Figure 8: M 1:750 Section A-A of Industrial Area (Blue) and Office Area (Green) | 3D Visualisation

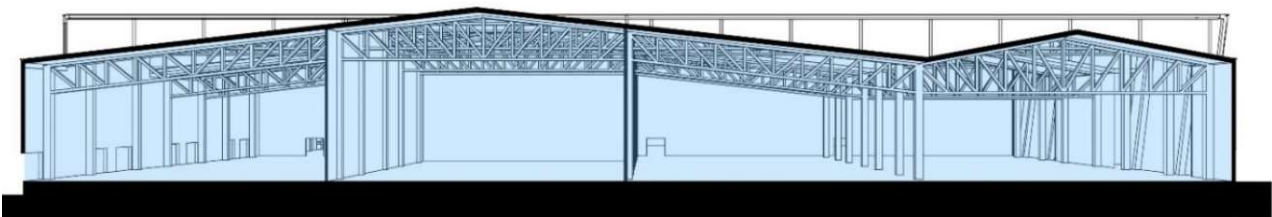


Figure 9: M 1:750 Section B-B of Production Area | 3D Visualisation

In *Table 3*, the rooms of each conditioned zone of the *ArchiCAD* BIM model are listed.

Office Area		REFERENCE ARCHICAD BIM MODEL	
Floor	Zone	Gross Floor Area [m <sup>2</sup> ]	Volume [m <sup>3</sup> ]
0.Floor	Office GF	741,32	2 668,76
1.Floor	Office 1.F	898,61	3 234,11
2.Floor	Office 2.F	781,23	4 687,38
		<b>2 421,16</b>	<b>10 591,128</b>
Industrial Area		REFERENCE ARCHICAD BIM MODEL	
Floor	Zone	Gross Floor Area [m <sup>2</sup> ]	Volume [m <sup>3</sup> ]
-1. Floor	Ind. B	778,03	2 022,88
0.Floor	Ind. GF1	1 358,11	4 889,21
0.Floor	Ind. GF2	16 550,15	264 802,41
1.Floor	Ind. 1.F	810,04	2 916,14
2.Floor	Ind. 2.F	435,93	2 833,55
		<b>19 932,26</b>	<b>277 464,16</b>

*Table 3: Zone 1 – Seizes of the Reference Office and Industrial Area*

#### 4.2. Structure of Variant Study

The steps of the variant study are as followed:

- Testing of two BIM to EPC Workflows (*ArchiCAD* to *ArchiPHYSIK* (A) and *ArchiCAD* to *SIMULTAN* (S)). A customised facade system (C) is used to obtain EPC A.C. and S.C.
- Improving both BIM to EPC Workflows to avoid occurring problems. A standard facade system (S) is used to obtain EPC A.S. and S.S.
- Replacement of the standard facade system by a high-end facade system (H) directly in the Energy Performance Tools to obtain EPC A.H. and S.H.

The first workflow (A) operates with the software *ArchiCAD 22* (developed by *Graphisoft*) and *ArchiPHYSIK 17.0.34* (developed by *A-Null Development GmbH*). This process is already well-established in the design practice in Austria. *ArchiCAD* is a BIM software, which is used especially by architects and has interfaces to various other software to support a collaborative way of working in an interdisciplinary team (*Graphisoft, 2021*). *ArchiPHYSIK* is a building physics software that is specialised on energy performance analysis (*A-NULL Development GmbH, 2021*). In this thesis the *ArchiCAD* BIM Model LoD300 is transferred via an Add-on as APS-file to *ArchiPHYSIK* to obtain an EPC.

The novel workflow (S) starts with the same *ArchiCAD* BIM Model LoD300, which is transferred to *SIMULTAN*. This tool is a collaboration data platform that is currently being developed at the Institute



E207-2 at the Vienna University of Technology. The data of this tool can be transferred for example to Excel-Calculation-Tools. In this way various simulations and calculations can be executed. At the end of this *ArchiCAD* to *SIMULTAN* workflow relevant data is exported to the so-called *TopPhiCO2* Excel-Tool where the EPCs are calculated. This Excel-Calculation-Tool is also currently being developed at the Institute E207-2 at the Vienna University of Technology (SIMULTAN Wiki, 2021). *The latest versions of the effective date 12<sup>th</sup> March 2021 are: SIMULTAN Version: 0.2.104 and TopPhiCo2\_FassungSIMULTAN\_90*

The first step is testing the workflows and generating EPC A.C. and EPC S.C. by using a customised facade system (C). Both workflows are evaluated based on their data model and geometrical model management, just as data loss, interoperability etc. To avoid the occurring data loss and high expenditure of time, improved workflows and guidelines are developed to efficiently transfer a BIM model to EP Tools and obtain EPCs. In the second step, these improved workflows are applied to generate EPC A.S. and EPC S.S by using a standard facade system (S). In the third step, two additional EPCs (A.H and S.H) are created by replacing the standard facade system by a high-end facade system (H) directly in the EP Tools *ArchiPHYSIK* and *SIMULTAN*.

The customised facade system was developed for the reference object in the design studio in 2017/2018. The standard as well as the high-end facade system were verified as usually used facade systems for industrial buildings as part of a bachelor thesis by Christoph Appl (2020).

All used facade systems are listed in *Table 4*. The used interior constructions are listed in *Table 5*.

Customised Facade System			
Exterior Wall Construction U-Value: 0,154		Exterior Basement Wall Construction U-Value: 0,234	
Wood Tiles	20mm	Filter Fleece	5mm
Battens with Air between	40mm	Insulation XPS	150mm
Mineral Insulation	150mm	Seal 3 Layers	10mm
Moisture Barrier	1mm	Bituminous Coat	1mm
CLT	60mm	Reinforced Concrete	300mm
Coating	1mm	Coating	1mm
Roof Construction 1 U-Value: 0,147		Roof Construction 2 U-Value: 0,165	
Wood Tiles	50mm	Fibre-Cement Tiles	60mm
Battens with Air between	30mm	Gravel Fill	40mm
Counter Battens with Air between	50mm	Filter Fleece	3mm
Seal 2 Layers	1mm	Seal 2 Layers	1mm
Mineral Insulation	150mm	Insulation XPS	180mm
PE-Fllm	1mm	Bituminous Coat	1mm
CLT	200mm	CLT	200mm

Base Slab Construction 1 U-Value: 0,318		Base Slab Construction 2 U-Value: 0,248		Base Slab Construction 3 U-Value: 0,315	
Coating	2mm	Carpet	5mm	Tiles	20mm
Screed	80mm	Screed	80mm	Waterproofing Film	1mm
Reinforced Concrete	370mm	Film	1mm	Screed	80mm
Lean Concrete	30mm	Sound Insulation	30mm	Reinforced Concrete	370mm
Seal 3 Layers	10mm	Gravel Fill	30mm	Lean Concrete	30mm
Insulation XPS	100mm	Reinforced Concrete	370mm	Seal 3 Layers	10mm
Lean Concrete	100mm	Lean Concrete	30mm	Insulation XPS	100mm
		Seal 3 Layers	10mm	Lean Concrete	100mm
		Insulation XPS	100mm		
		Lean Concrete	100mm		
<b>Standard Facade System</b>					
Exterior Wall Construction U-Value: 0,255			Exterior Basement Wall Construction U-Value: 0,236		
Metal Sheet	0,3mm	Filter Fleece	5mm		
Battens with Air between	30mm	Insulation XPS	150mm		
Steel Pipe between Mineral Insulation	150mm	Seal 3 Layers	10mm		
		Bituminous Coat	1mm		
		Reinforced Concrete	300mm		
		Coating	1mm		
Roof Construction 1 U-Value: 0,2			Roof Construction 2 U-Value: 0,2		
Metal Sheet	3mm	Fibre-Cement Tiles	30mm		
Battens with Air between	20mm	Gravel Fill	40mm		
Counter Battens with Air between	30mm	PE-Film	2mm		
PE-Film	2mm	Fleece	3mm		
Fleece	1mm	Mineral Insulation	160mm		
Mineral Insulation	160mm	Film	1mm		
Film	1mm	Bituminous Coat	1mm		
Bituminous Coat	1mm	Reinforced Concrete	200mm		
Reinforced Concrete	200mm				
Base Slab Construction 1 U-Value: 0,4		Base Slab Construction 2 U-Value: 0,396		Base Slab Construction 3 U-Value: 0,396	
Reinforced Concrete	370mm	Screed	80mm	Tiles	0,020mm
Seal 3 Layers	10mm	Reinforced Concrete	370mm	Waterproofing Film	0,001mm
Insulation XPS	80mm	Seal 3 Layers	10mm	Screed	80mm
		Insulation XPS	80mm	Reinforced Concrete	370mm
				Seal 3 Layers	010mm
				Insulation XPS	80mm
<b>High-End Facade System</b>					
Exterior Wall Construction U-Value: 0,276			Exterior Basement Wall Construction U-Value: 0,236		
Wood Tiles	9mm	Filter Fleece	5mm		
Battens with Air between	30mm	Insulation XPS	150mm		
Counter Battens with Air between	60mm	Seal 3 Layers	10mm		
Wooden Columns (Mineral Insul. betw.)	100mm	Bituminous Coat	1mm		
OSB Board	18mm	Reinforced Concrete	300mm		
		Coating	1mm		

Roof Construction 1		Roof Construction 2			
U-Value:		U-Value:			
OSB Board	50mm	Fibre-Cement Tiles	30mm		
Battens with Air between	20mm	Gravel Fill	40mm		
Counter Battens with Air between	30mm	Filter Fleece	3mm		
Seal 2 Layers	1mm	Seal 2 Layers	1mm		
Film	1mm	Insulation XPS	180mm		
Mineral Insulation	140mm	Bituminous Coat	1mm		
Bituminous Coat	1mm	Concrete Concave Slab	500mm		
Concrete Concave Slab	500mm				
Base Slab Construction 1		Base Slab Construction 2		Base Slab Construction 3	
U-Value: 0,375		U-Value: 0,328		U-Value: 0,37	
Coating	2mm	Carpet	5mm	Tiles	20mm
Screed	30mm	Screed	80mm	Waterproofing Film	1mm
Reinforced Concrete	370mm	Film	1mm	Screed	80mm
Seal 3 Layers	10mm	Sound Insulation	30mm	Reinforced Concrete	370mm
Insulation XPS	80mm	Reinforced Concrete	370mm	Seal 3 Layers	10mm
Lean Concrete	100mm	Seal 3 Layers	10mm	Insulation XPS	80mm
		Insulation XPS	60mm	Lean Concrete	100mm
		Lean Concrete	100mm		

Table 4: Applied Envelope Constructions: Customised, Standard, and High-End Facade Systems

Interior Constructions used in all Variants					
Ceiling Construction 1		Ceiling Construction 2		Post and Beam Facade	
U-Value: 0,465		U-Value: 0,322		U-Value: 1	
Tiles	20mm	Carpet	5mm		
Waterproof Film	1mm	Screed	80mm		
Screed	80mm	PE-Film	1mm		
PE-Film	1mm	Sound insulation	30mm		
Gravel Fill	20mm	PE-Film	1mm		
CLT	200mm	Gravel Fill	20mm		
Air	150mm	CLT	200mm		
2x Plasterboard	25mm	Air	150mm		
		2x Plasterboard	25mm		
Interior Wall Construction 1			Interior Wall Construction 2		
U-Value: 0,511			U-Value: 0,437		
2x Plasterboard		25mm	2x Plasterboard		25mm
Air		30mm	Air		30mm
Mineral Insulation		30mm	Mineral Insulation		30mm
2x Plasterboard		25mm	CLT 2x Plasterboard		40mm
					25mm

Table 5: Interior Constructions, that are used in all Variants.

The obtained results are evaluated within a variant study. The efficiency of the workflows is assessed by comparing and verifying the data transfer by means of data loss, interoperability, workload, expenditure of time, likewise the diverse potentials and deficits of the EP Tools. The practicability of creating variants in the EP Tools is of great interest to improve the energy efficiency and building performance. Further, for this reason, the EPC results of both workflows are compared and discussed.

The focus is on similarities of the results generated by *ArchiPHYSIK* and *SIMULTAN*, as well as the impact on the buildings energy performance due to the quality of the three applied facade systems (customised, standard and high-end).

Before the transfer can be started, a building envelope borderline must be defined. In this thesis this is the contour of the building.

Furthermore, the interior structural elements (frames etc.) are irrelevant for the EPCs and therefore can be neglected. The same material values and parameters are applied in both EP Tools.

In this thesis the minimum requirements of the U-Values, displayed in *Table 6*, provided in the OIB RL 2015 are used (OIB RL 6, 2015). The current official version is the OIB RL 6 2019. (OIB RL 6, 2019) The previous version of 2015 is used because one of the tools is operating only with the previous version.

Construction Element	U-Value [W/m <sup>2</sup> K] OIB RL 6 2019	U-Value [W/m <sup>2</sup> K] OIB RL 6 2015
Exterior Walls	0,35	0,35
Basement Walls	0,40	0,40
Walls dividing different dwelling, factory, or operation units	1,30	0,90
Windows, Doors with glass in non-domestic buildings	1,70	1,70
Diverse Translucent / Transparent Elements (vertical)	1,70	1,70
Roof-Window	1,70	1,70
Doors (opaque)	1,70	1,70
Gate (sliding gate etc.)	2,50	2,50
Ceilings and Sloped Roofs	0,20	0,20
Base (in contact with the soil)	0,40	0,40

*Table 6: Shows the minimum required values of the U-Value according to OIB RL 6 2019 (official current version) and OIB RL 6 2015 for the facade systems that are used in the master thesis. Version of 2015 is used in the master thesis. (OIB RL 6, 2015)*

## 5. Results: Evaluation of Workflows and Variant Study

### 5.1. Testing of Workflows – Variant 1: Customised Facade System

The variant study of this thesis is based on testing two BIM to EPC workflows (A and S). Both workflows start with the same BIM model LoD300 which is transferred to two Energy Performance Tools. In both EP Tools three EPCs are calculated. The first approach is testing recommended workflows and applying a customised facade system (C). The second approach is done by improving both tested workflows and using a standard facade system (S). And the third one is created by changing the standard facade system to a high-end facade system (H) directly in the Energy Performance Tools. In addition to improving workflows, the variant study requires the use of the three applied facade systems – customised, standard, and high-end. In the end the EP tools and results are compared and their potentials as well as deficits are demonstrated and interpreted.

The customised facade system used for EPC A.C. and EPC S.C. is listed in *Table 4*.

The interior constructions are the same in all variants and are listed in *Table 5*.

#### 5.1.1. ArchiCAD to ArchiPHYSIK Workflow

This section describes the established workflow of an *ArchiCAD* Model LoD300 to the Energy Performance Software *ArchiPHYSIK* to create an Energy Performance Certificate according to OIB RL6. The diagram in *Figure 10* shows a semi-automated BIM to EPC workflow based on Leonard Donkor (2019). This shown workflow is especially for buildings with one conditioned zone. Before a model can be transferred from *ArchiCAD* to *ArchiPHYSIK* several things need to be considered. A pre-process is necessary. The following part describes the suggested BIM to EPC workflow more closely until an EPC can be generated by applying it on a building with two zones.

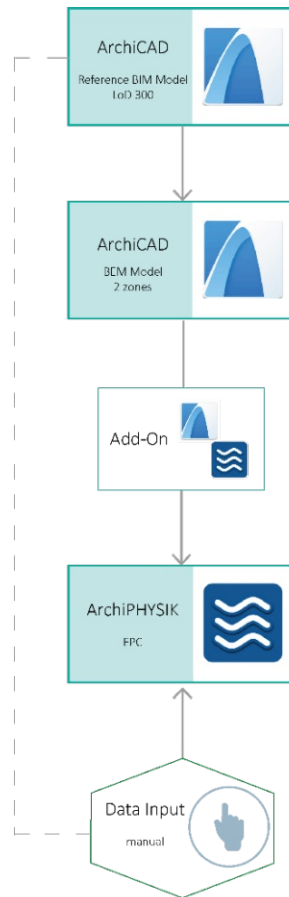


Figure 10: Testing of the BIM to EPC workflow - ArchiCAD to ArchiPHYSIK - based on Leonard Donkor (2019)

#### 5.1.1.1. Transfer to ArchiPHYSIK

##### Creating a new project in ArchiPHYSIK

When a planner starts a new *ArchiPHYSIK* project, a plane project or a template can be used. In this case, a plane project was used. After opening the project, essential information needs to be filled in like described below in *Table 7*.

Project Data	
Standards for	Energy Performance Certificate AUT 2015
Purpose	Building Submission
Object Data	
Building Type	Office and Event Location
Affiliated Municipality	81135 - Völs
Geographical Position (filled in automatically via the Location)	Longitude: 11°20' 0" O Latitude: 47° 15' 0" N See Level: 594m
Address	Florianiweg 16a A – 6176 Völs

Climate Data (filled in automatically via the Location)	
Heating Degree Days	3.715 Kd
Heating Days	248 d
Outdoor Temperature	-12,0 °C
NAT-13	20,9 °C
Temperature Region	North – Foehn Area

Table 7: Shows important data which was needed to be filled in or was automatically generated by filled in information.

The next step is defining further necessary data for the calculations, just like the facade systems that are responsible to keep the heat inside and the cold outside the house in winter, and contrariwise in summer for an energy-efficient building.

### *Creating Construction Elements in ArchiPHYSIK*

Walls, roofs, and bases are relevant for calculating an Energy Performance Certificate of a building. *ArchiPHYSIK* has a user-friendly interface with a special data assistant, and an automatic U-value, moisture, and noise calculator. The data assistant is connected to online data libraries that hold a big variety of materials and default construction elements. To name only a few of the libraries, the software is linked to baubook, Öko-Index, Baisc Europe, Basiskatalog Österreich, Baumit, and multiple material manufacturers: GEOCELL, Knauf, Röfix, Rockwool Österreich, Saint-Gabain ISOVER Austria, Senftenberger Ziegelwerk, Wienerberger, etc.

*ArchiPHYSIK* can receive the construction elements of *ArchiCAD* models, but according to Donkor (2019, p. 67) unfortunately, some property parameters of materials are lost in the transfer. For this reason, the author decided to create all elements in *ArchiPHYSIK* before importing the BEM model. All constructions are created with the help of the material data assistant. The procedure of adding a new construction element is quite straightforward by adding new material layers via drag and drop using the materials of the data assistant. The only parameter which has to be adjusted manually is the thickness. This drag and drop step is repeated until all layers of the construction and finally, all the needed walls, roofs, bases, ceilings, and windows are contained in the header construction elements.

Although the data assistant has access to various libraries, it might not be possible to find every material that is needed. No result can be found for “Dampfbremse” – a breathable membrane in English. But when searching for “diffusionsoffen” – in English: breathable – there are some polyethylene films (PE-Film) with this character. These two are the very same material. Another issue that appears while searching is being unable to choose a specific library where a material can be searched in. Moreover,

the moisture calculation appears to have some troubles with insulation, because, when using default insulation, the element is endangered to have condensate. However, when applying insulation from a listed company the condensate calculation is without moisture danger. Both insulations have the very same parameters, but still, a difference in the result occurred.

Nevertheless, the data assistant is a very user-friendly feature that helps especially planners who are not specialised in physical properties of materials. It simplifies and accelerates the process of creating construction elements very fast. When working on an *ArchiPHYSIK* project, the planner can import construction elements from another project via the data assistant.

### *Building Utilisation and HVAC*

For creating an EPC, more information is relevant than the ones mentioned above. The building utilisations, facilities, and building services also need to be considered and filled in the *ArchiPHYSIK* project. When defining zones for the building the utilisation settings can be selected under the header “building”. In this reference object, the office utilisation is used for the first zone and the event location utilisation for the second zone (industry area). The header “facilities” allows the user to choose building services and systems like heater, water heater, ventilation and air conditioning, lighting, solar plant, cooling, photovoltaics, and energy demand.

### *Pre-Processing BIM to BEM in ArchiCAD*

The reference model was modelled in *ArchiCAD 21* and reopened in *ArchiCAD 22*. It consists of two zones – office and industry (here calculated as event location) area. One of the reasons why there are only two zones in the building is that using only two zones is already representative for an open data transfer of a multizone building.

In order to transfer the *ArchiCAD* model to *ArchiPHYSIK* an Add-On provided by *A-Null Development GmbH* needs to be installed in *ArchiCAD*. Before the Add-On can be used without errors, the BIM model LoD300 has to be pre-processed and simplified to a Building Energy Modelling (BEM) model. This is necessary because BIM models LoD300 contain too much information for the transfer to *ArchiPHYSIK*. According to [buildinformed.com](http://buildinformed.com) (2021) the LoD300 is the needed level for submissions. *A-Null Development GmbH* provides a guideline and videos on how to pre-process a BIM model LoD300 to a BEM model that can be exported via the Add-On, on their homepage ([A-NULL Development GmbH](http://A-NULL Development GmbH), 2021).



Furthermore, this Add-On can only be used for one zone in each export. The user has to export the zones separately. In this project, the focus is firstly set on the office zone of the building. The Building Energy Model consists of the building envelope and the floors. Neither beams, columns, staircases, handrails, furniture, room stamps nor interior walls are relevant. In the matter of multiple zone buildings, the interior walls that separate zones should be visible as well. Every visible element is exported if the Add-On can detect it. *A-Null Development GmbH* suggests using an extra layer combination in *ArchiCAD* to hide all other elements that are not needed for the export (2021). In the first step all the dispensable interior walls, furniture, beams, columns are hidden until only the envelope of the two desired zones is left. Yet, when the BEM model is modelled in the constructional right way, and unessential elements are hidden, some elements still cause errors like the attic or roof overhangs. *A-Null Development GmbH* states, this can be corrected for the BIM to BEM workflow by copying the wall and roof to a BEM layer and trim them. However, in this case, it is not possible, and the author just trims the original walls.

When the envelope is the only remaining object, the Add-On can be applied. Here the first problem appears – room stamps cannot be created. This issue usually occurs when walls are not connected in the right way. The author tries to work around this issue by setting the room stamps manually, which works. It is possible to apply the special Add-On.

This feature contains seven steps to create an APS-data file. To start the export, the user has to go to a 2D window because the exporter assistant does not start in the 3D window. The first step is choosing the floors that are supposed to be exported. Secondly, 3D room stamps have to be set in order to define the envelope. In step three the so-called red line is set– this means defining the outermost layer of a construction and the outline of a building. Step four defines the rooms/volumes that are exported. Via volumes, the gross floor area is verified in step five. For the sixth step all elements that will be exported are listed and can be edited. The seventh and final step, is the thermal model export to receive an APS-data file. After this the Add-On can be applied. The generated APS-data file is compatible to be imported to *ArchiPHYSIK*.

As a result of the described process, hardly any elements are imported to *ArchiPHYSIK*.

This transfer result means the user has to make sure all walls are trimmed and connected in the right way to create room stamps automatically. The walls are created as multilayer construction which can be imported to *ArchiPHYSIK*. The intersection and connection of the material can be changed by adapting the material weight. This means changing the priority of the material in the material properties. Concrete and brick walls should be the ones with the highest weight. The right connection

of constructions needs to be changed before exporting one conditioned area since the geometrical volumes are reaching into each other and creating some difficulties with the connection. The author separates these walls and floors into two pieces to avoid further troubles.

In the simplified model of the office zone, the room stamps can be created automatically, except for the room on the second floor. The room consists of three walls and one roof that is steeply sloping until it reaches the floor. For this reason, the author models a small test project to see if a room stamp can be set with one of the walls being a roof element. The test result show that a room stamp cannot be created. The solution of this problem is adding a little wall to obtain a real connection (floor to wall and wall to roof). Finally, in this way, all room stamps can be created automatically, and the export steps are continued. At the third step, not all construction elements are listed. Going to step four the export window just disappears and ends the operation. It is found out that even though room stamps can be created and the material weight is set, problems still can occur. The conclusion of this is to simplify the model even further. In prospect, to avoid further connection and intersection problems, single-layer constructions are used.

After changing all elements from multi-layer to single-layer, the export of the *ArchiCAD* model works and an APS-file of the office area is created. The import of the file to *ArchiPHYSIK* is easy, especially the construction connection to the already prepared elements. After a close inspection of the imported surfaces, it is clear that not all the elements arrived in the EP software. The office building only consists of one wall facing the south, as well as only three roof surfaces after the import.

Another small test project is modelled to verify if the *ArchiCAD* facades can be transferred. Just like a few other elements, *ArchiCAD* facades cannot be received by *ArchiPHYSIK*. According to *A-Null Development GmbH*, hatchings can be transferred via the Add-On Tool. Due to this reason, all parts of the office glass facade are covered with hatchings in all elevations. Unfortunately, after the transfer, there was only one hatching remaining per elevation. Given four existing hatchings with different sizes, the programme randomly chooses one hatching and multiplies it four times. After reporting this issue, *A-Null Development GmbH* admits that this is a software bug that appears only in *ArchiCAD 22*. Supposedly, this bug does not occur in the previous or the follow-up versions. The option of changing the facade into a wall for the export and then connecting it to a window during the import is not possible either because walls cannot be changed to windows in *ArchiPHYSIK*. This leads to the result that in the case of that glass facade, these surfaces need to be added manually to *ArchiPHYSIK* in the end. To receive the right square meters and room stamp, the glass facade needs to be changed into a wall anyway.

After the transfer, another mistake is discovered. When checking the received surfaces, one wall facing north is originally facing south in the *ArchiCAD* model. This needs to be changed in the end by deleting the surface in the north wall and adding it to the south wall.

Not only facades are causing problems, but also roof surfaces. *ArchiPHYSIK* does not receive the multiple sloping roofs, which also need to be added manually in the end.

The industrial zone needs to be pre-processed as well, after completing the transfer of the office area. Due to the overlapping volumes of both zones, the connections of walls, roofs, and ceilings are edited. Preparing the BEM model for the second zone seems to be a bigger challenge, also caused by the multiple sloping roof surfaces.

By applying the export assistant connection, problems occur again, and room stamps cannot be generated. Furthermore, the hidden structures cause trouble. After trying several times to connect the monolithic construction elements differently, the room stamps cannot be created except for the one in the basement. For the other rooms, the error message window states every time that the walls are not connected, and a room cannot be found. Finally solving this problem by separating and reconnecting the walls, another error message appears. Some walls are sloped and after the transfer, the walls have a value of 0 square meters. This fact is proven in a small test project. To receive the right value for those walls, they are set completely vertical. Another problem that is caused by the sloped wall is the connection between roofs and walls – only completely vertical walls can be trimmed.

After this time-consuming process room stamps of the pastry production area can be created. But for the big hall, it takes another tedious process to find a solution. In the first step the height of 1m has to be applied to be able to generate the room stamp. After this, the height is changed to the actual height and is trimmed by the roof. But once again, not all elements are imported to *ArchiPHYSIK*. This is also shown by a dialog window in *ArchiCAD*. Only a few roof surfaces are delivered to *ArchiPHYSIK*. The surfaces are still visible in the Add-On exporter assistant but are lost in the transfer. The shape of the roof is created by multiple sloping surfaces, which cause these problems. This is verified in another small test project. Those missing surfaces also need to be added manually. Taking a closer look at the roof, also the vertical walls are missing – exactly these that are also trimmed by a roof situated below the wall. These walls are added manually as well in the end.

The post-process in *ArchiPHYSIK* can be started in the next step of the workflow. Since not all geometrical surfaces are imported to the Energy Performance Tool, the planner needs to make sure all geometries (surfaces and volumes) are added manually in the end.

Finally, when both zones are more or less successfully imported to ArchiPHYSIK the post-process can be started. The user needs to verify which elements arrived in ArchiPHYSIK and which ones did not. For tracking the received, the wrong and missing elements, the author wants to use the evaluation option of ArchiCAD – a feature to list all used elements of the project in a document. Unfortunately, the listed elements include the hidden ones as well. Therefore, the author manually creates a list to do the verification, which is visualised in the Table 8 below.

Office Area – Missing Elements						
Floor	Name of Layer	User ID	m <sup>2</sup>	Direction	Status	
Ground Floor	AW01_Glass Facade	Wand-191	151,37	South	Manually Added	
		Wand-191	46,42	East		
		Wand-191	117,03	North		
First Floor		Wand-191	198,85	South		
		Wand-191	21,41	East		
		Wand-191	95,30	North		
Second Floor		Wand-268	261,11	South		
		Wand-194	30,30	South		
		Wand-191	48,06	East		
Second Floor		AW02-CLT Wall	Wand-187	7,99		South
Roof	Da02	Dach-010	418,86	Horizontal		
	Da01	137	68,66	East 45 Degrees		
		136	195,54	East 45 Degrees		
		Dach-012	38,44	Horizontal		
		Dach-011	45,46	Horizontal		
		140	66,67	East 45 Degrees		
		134	596,47	West 30 Degrees		
Industry Hall Area - Missing Elements						
Floor	Name of Layer	User ID	Quantity	m <sup>2</sup>	Direction	Status
Ground Floor	AW01_Glass Facade	Wand-272	4	177,42	South	Manually Added
		Wand-275	3	177,42	North	
		Wand-270	2	45,97	South	
		Wand-270	2	85,96	South	
		Wand-270	2	43,26	South	
		Wand-271	1	45,97	North	
		Wand-271	1	85,96	North	
		Wand-271	1	43,26	North	
		Wand-187	1	46,36	South	
		Wand-188	2	46,36	North	
Wand-198		1	164,43	South		
First Floor		Wand-192	1	25,37	East	
		Wand-198	1	93,43	South	
Second Floor		Wand-192	1	58	East	
		Wand-274	1	98,23	South	
		Wand-272	4	74,88	North	
		Wand-275	4	74,88	South	
Ground Floor	AW02_CLT	Wand-265	1	686,77	South	
Roof	Window	Decke-036	1	257,72	Horizontal	
Roof	Da01	2	4	560,25	West 15 Degrees	Manually Added
		191	2	558,01	West 15 Degrees	
		4	4	553,77	East 15 Degrees	
		Dach-008	1	454,89	Horizontal	
		Dach-008	1	1.561,75	Horizontal	

		189	2	203,18	West 30 Degrees	
		194	2	384,61	West 30 Degrees	
		190	2	194,75	East 30 Degrees	
		193	2	193,66	East 30 Degrees	

Table 8: This list reveals all surfaces that need to be added manually.

Office Area		ARCHICAD <b>BEM</b> MODEL		ARCHIPHYSIK	
Floor	Zone	Gross Floor Area [m <sup>2</sup> ]	Volume [m <sup>3</sup> ]	Gross Floor Area [m <sup>2</sup> ]	Volume [m <sup>3</sup> ]
0.Floor	Office GF	713,11	2.995,06	713,11	2.368,16
1.Floor	Office 1.F	899,53	3.076,39	899,53	2.995,84
2.Floor	Office 2.F	814,29	4.071,45	814,29	4.043,18
		<b>2.426,93</b>	<b>10.142,90</b>	<b>2.426,93</b>	<b>9.407,18</b>
Industrial Area		ARCHICAD <b>BEM</b> MODEL		ARCHIPHYSIK	
Floor	Zone	Gross Floor Area [m <sup>2</sup> ]	Volume [m <sup>3</sup> ]	Gross Floor Area [m <sup>2</sup> ]	Volume [m <sup>3</sup> ]
-1. Floor	Ind. B	788,25	2.364,75	788,25	2.837,50
0.Floor	Ind. GF1	1.381,78	5.803,48	1.381,66	5.526,62
0.Floor	Ind. GF2	16.504,00	231.056,00	16.503,99	242.396,20
1.Floor	Ind. 1.F	846,32	3.554,54	846,26	3.385,04
2.Floor	Ind. 2.F	433,03	3.226,07	433,03	3.464,21
		<b>19.953,38</b>	<b>246.004,84</b>	<b>19.953,19</b>	<b>257.609,57</b>

Table 9: GFA and V of the BEM Models of the Office and Industrial Area in ArchiCAD and ArchiPHYSIK

### 5.1.1.2. Energy Performance Certificate in ArchiPHYSIK

After the input of data and the transfer of geometry, the EPC is finally created. In the header “Energy Performance Certificate”, the results of each zone are listed as well as the combined energy performance of both. The header “form” includes the related documents like the facade systems and other construction elements. These documents are printable. Hereinafter, the obtained EPC is summarised in Table 10, Table 11, Figure 11 and Figure 12. All abbreviations describe location-based values. The listed GFA and V are conditioned zones.

EPC A.C.	Unit	Office Area
GFA	m <sup>2</sup>	2.426,93
V	m <sup>3</sup>	9.407,20
HED	kWh/m <sup>2</sup> a	45,21
PED	kWh/m <sup>2</sup> a	187,39
EED	kWh/m <sup>2</sup> a	108,67
CO <sub>2</sub>	kg/m <sup>2</sup> a	30,77
f	-	0,763

Table 10: Results of the EPC A.C – Office Area

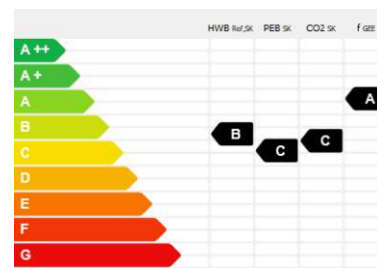


Figure 11: EPC Category Scale A.C - Office Area

EPC A.C.	Unit	Industrial Area
GFA	m <sup>2</sup>	19.953,19
V	m <sup>3</sup>	257.609,57
HED	kWh/m <sup>2</sup> a	63,66
PED	kWh/m <sup>2</sup> a	283,44
EED	kWh/m <sup>2</sup> a	166,83
CO <sub>2</sub>	kg/m <sup>2</sup> a	47,40
f	-	0,306

Table 11: Results of the EPC A.C – Industrial Area

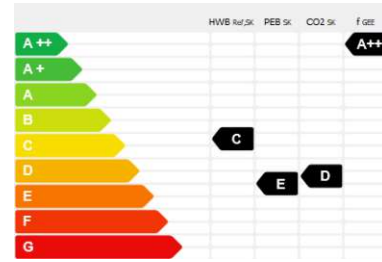


Figure 12: EPC Category Scale A.C - Industrial Area

### 5.1.1.3. Occurring Problems

By testing the BIM to EPC workflow for buildings with one conditioned zone based on the master thesis of Leonard Donkor (2019) on a multizone building, still a lot of problems occurred as depicted in Section 5.1.1.1. Some errors were the same, but due to the second zone and more complex geometry of the building other problems appeared. In *Figure 13* these problems are visualised.

Based on the analysis mentioned above, an improved workflow is proposed in *Section 5.2.1.*, for which a guideline is provided in *Section 5.2.1.3.*

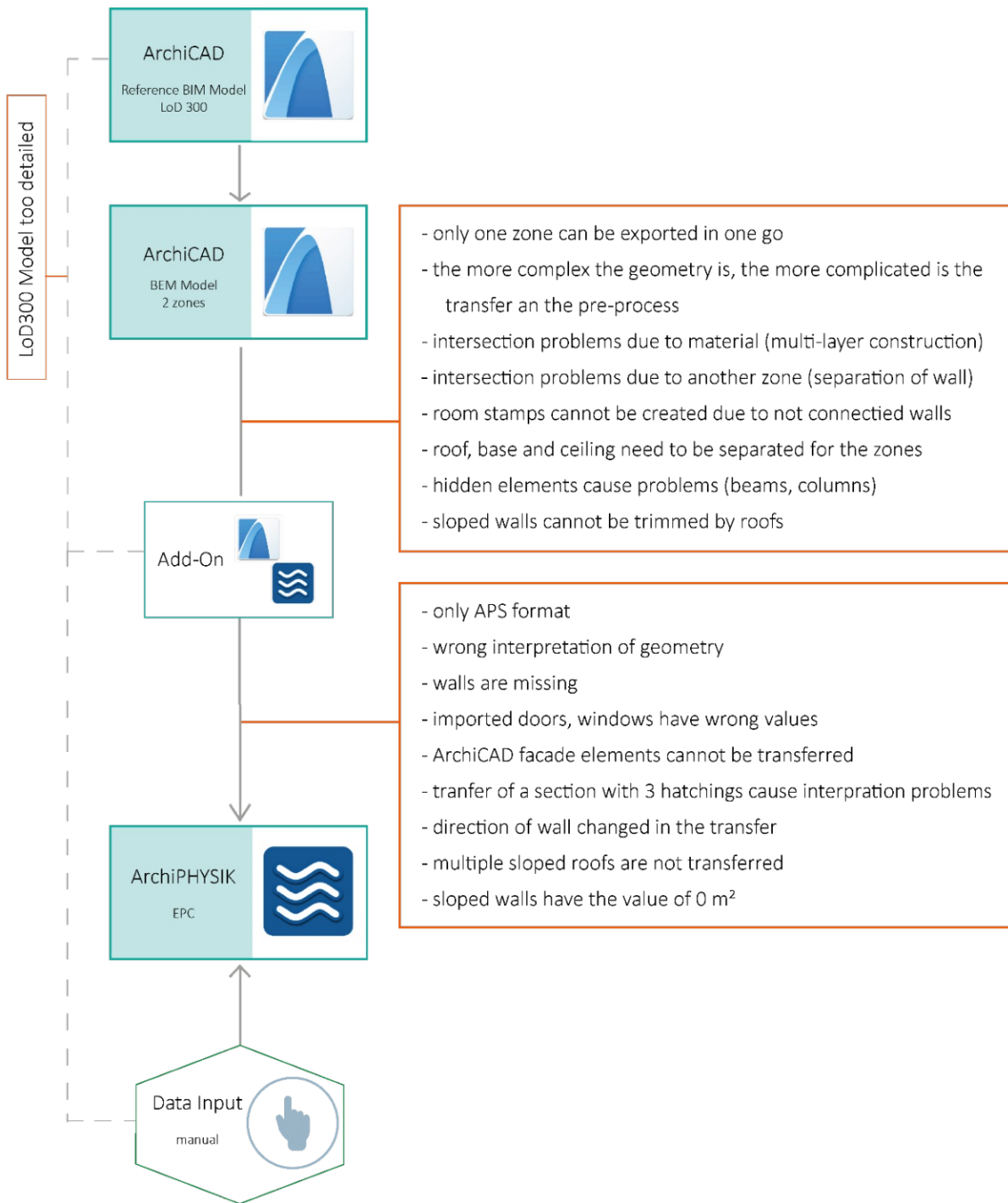


Figure 13: Visualisation of the occurring problems in the ArchiCAD to ArchiPHYSIK Workflow for multizone buildings.

### 5.1.2. ArchiCAD to SIMULTAN Workflow

This section describes the novel workflow of an *ArchiCAD* Model LoD300 to the new software *SIMULTAN* to create an Energy Performance Certificate according to OIB RL 6 2015. *SIMULTAN* is currently being developed at the Institute of Material Technology, Buildings Physics and Building Ecology at the Vienna University of Technology. Therefore, the author had the possibility to work with two user-interfaces (UI) of the *SIMULTAN Component Builder* – the old and the new one. The new UI is more user-friendly, has more features, and a user-management. But of course, the developer group still improves the software and solves occurring problems. Therefore, new features are published frequently, which also affected the ease of the workflow, which is visualised in the following *Figure 14*.

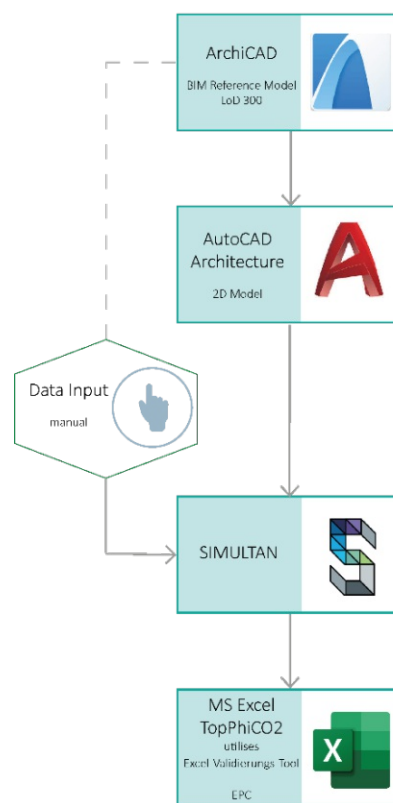


Figure 14: Testing of the BIM to EPC workflow - ArchiCAD to SIMULTAN - based on the developer team (Pascaleva & Steiner, 2020)

#### 5.1.2.1. Transfer to SIMULTAN

##### Creating a new Project

When opening a new *SIMULTAN* project, the user already ought to set an administrator username and a password. The administrator is able to create new users as already mentioned in *Section 3.5*. In this case, the author decided to stay in the position of the administrator to be authorised to do everything



in the project. *SIMULTAN* neither provides templates of building services, nor construction elements, nor is the software linked to an online library (for example material library). Everything needs to be created and filled in by the user. The first things to be defined are the construction elements, then rooms, utilisation profiles, HVAC, building services, etc.

### *Pre-Processing: Creating Materials, Layers and Construction Elements*

To define construction elements, it is necessary to create a material library in the first step since *SIMULTAN* is not linked to any online material library. Due to this reason all specific parameters of each used materials are filled in. The material information can be found online at [baubook.info](http://baubook.info), [masea-ensan.de](http://masea-ensan.de), and other official online material libraries. In this case, the author also wants to make sure that all used parameters in *SIMULTAN* are identical to those in *ArchiPHYSIK*.

Components can be defined in the property “slot” as acoustics, air conditioning, artificial light calculation, communication, composite (construction), connected to, cost, distribution, electricity, element, fire, safety, generator, geometrical area, geometrical length, geometrical object, geometrical size, geometrical volume, geo-reference, heating, humidity, import, joint, layer, list, material, MSR, natural light, opening, requirement, sewage, specification, system, transportation, transportation channel, transportation part, tuple or water. In this case, the component is a material which has various parameters. Parameters describe components and give them specific properties, just as specific heat capacity, conductivity, water vapour diffusion resistance, dry density, etc.

After all needed materials and their properties are added, the constructions are prepared. This is done by creating layers, where each one references a certain material. In general, using references saves time when material properties need to be changed because the user has to edit parameters in only one place. In addition to the existing material parameters, new ones are added to each layer. These new properties define the thickness and the position of the layer – if they are inside the construction, in contact with soil, or rather with air outside. To each construction component, a calculation for the total thickness is added – the layer thickness values are added up. Another interesting calculation is the U-Value, which can also be gained easily by obtaining the resistance of each layer, then adding them up with the external and internal geometrical surface resistance value  $R_{se}$  and  $R_{si}$ , and therefore receiving the total resistance  $R$ . The U-Value is the reciprocal of  $R$ .  $U = 1/R$  in  $W/m^2K$  (Riccabona & Bednar, 2013, pp. 26,27).

When all constructions and layers are generated, new components for the assignment of surfaces are added. Each of these new components references one of the constructions. All parameters are

prepared to automatically reuse values from references. These construction assignment components are ready to be linked to surfaces. Not only surfaces are assigned to components, but also volumes. Therefore, a room list with components for each room is added and linked to volumes later.

### *Pre-Processing in AutoCAD*

For the purpose of creating an EPC with *SIMULTAN*, the 3D model needs to be modelled in the software as well. Unfortunately, the transfer via a BIM data file format – like IFC – is not possible. At present, February 2021, the *Geometry Viewer* can import DXF files only. DXF is a drawing interchange file format developed by *Autodesk*, which saves 3D geometrical information and can be converted to DWG files. (knowledge.autodesk.com) *ArchiCAD* has the option to save solo-PLN project files in DXF format, but still, the file appears unusable for *SIMULTAN*, due to hatchings, blocks, and more complex object data. The *Geometry Viewer* only operates with vertices, edges, faces, and volumes.

The developers recommended adapting and simplifying each floor plan in *AutoCAD* (by Autodesk) and importing it via DXF to receive the accurate room sizes in *SIMULTAN*. (*SIMULTAN Wiki*, 2021) This is very useful when the building is more complex and contains a lot of rooms. The user decides to prepare and transfer all rooms and connect the volumes to the determined two zones in the *Geometry Viewer*, just like those in *ArchiPHYSIK* to obtain the same conditions in both workflows.

To finally transfer data to *SIMULTAN*, it is necessary to trace all walls with polylines. Therefore, the outline of the exterior walls and the axis of the interior walls are used. A new layer is added for this issue. The reason for tracing the outline and the axis is that *SIMULTAN* works with surfaces (*Geometry Viewer*) that get assigned to walls, floors, ceilings, roofs, doors, windows, etc. (*Component Builder*) in a further step. These elements have specific thicknesses which reach either inside, outside, or on both sides of volumes. For example, exterior walls reach into the volume and therefore the contour is traced. Furthermore, rooms (*Component Builder*) are defined by volumes (*Geometry Viewer*) and automatically adjust their room size when a wall construction's thickness is adapted – gross as well as net floor area. Columns and beams are neglected in *SIMULTAN* as well as in *ArchiPHYSIK* due to their irrelevance in the EPC simulation. They also cannot be visualised and calculated in a useful way in *SIMULTAN*.

For the tracing of the building envelope, it is essential to use multiple layers in *AutoCAD*, due to glass facades and opaque wall structures. After this process, a new *AutoCAD* DWG file is created, the layers with the polylines for tracing are isolated, copied by a basis point, and pasted into the new file at the position (X=0, Y=0, Z=0). All floor plans are manipulated and transferred as well, the only difference is the Z-axis, which differs depending on the floor height. In the end, this file holds only the borders of the

building and rooms of each floor. The user has to make sure that all lines are either connected, trimmed, or extended to avoid lines having an open end. All lines have to be part of a loop, since the *Geometry Viewer* requires these conditions. The file is saved in DXF format and ready to be imported to the *Geometry Viewer*.

The question might occur, why every BIM data that the *ArchiCAD* model holds is destroyed by using this workflow. However, directly in *SIMULTAN*, a new BIM model with a slightly different BIM concept and data structure is created as explained more closely in Section 3.5. *SIMULTAN*.

### *Pre-Processing in Geometry Viewer – Modelling a 3D Building*

The SIMGEO-file is added to the project explorer in the *Component Builder*. This is the file format of the *Geometry Viewer* – the 3D modelling tool of *SIMULTAN*.

The DXF-file is imported to the *Geometry Viewer* and appears in the exact position of the X-, Y-, and Z-axis as in *AutoCAD*. Since the used scale of *AutoCAD* can be set by users in m, cm, or even mm, it needs to be verified if scaling is essential for the new tool. The *Geometry Viewer* operates in meters. Compared to other modelling software, this UI switched the Y- and Z-axis of the coordinate system. To have a good modelling overview, the tool uses layers. These layers are able to contain sublayers depending on the user needs. The author creates layers for each floor and then several sublayers to hold the vertices, edges, and surfaces of windows, walls, etc. The 3D model of the *Geometry Viewer* is minimalistic and consists only of vertices, edges, faces, and volumes.

Surfaces are supposed to be generated automatically during the import. At this point, the user already moves the vertices, edges, and faces to the desired layer. The next step is modelling volumes, which describe the rooms. This is done by extruding the surfaces to the next floor. The sloped surfaces are causing no problem because edges can be moved easily. When modelling the dynamic roof, the user is strongly encouraged to pay attention when moving an element. Because this could affect more elements since they are connected after applying the operation “Clean-Up”. This feature deletes all double vertices, edges, and surfaces. The solution is to model new volumes, in this case, roof volumes. Later they are connected to the existing volumes. After connecting the volumes, the surface between them disappears automatically. Walls etc. appear as surfaces without any thickness. They need to be assigned to constructions of the *Component Builder* to visualise a thickness.

## Assignment of Components and Geometry

The 3D model in the *Geometry Viewer* and the components in the *Component Builder* are not connected automatically to each other, this is done manually. The created rooms and construction components need to be assigned to volumes and surfaces. This can be done in the *Geometry Viewer* by selecting one or more surfaces that should have the same construction. In the property editor, the option of generating a connection to a component is applied. In this way, the surfaces are able to be set as walls, roofs, etc. When components are assigned to surfaces and volumes, new parameters, surface- and volume-references are generated automatically. The parameters  $\Delta_{din}$  (delta thickness in) and  $\Delta_{dout}$  (delta thickness out) define the thickness of a construction. They are also an expression in which direction the layers are heading.  $\Delta_{din}$  means the element reaches into the volume and  $\Delta_{dout}$  means to the outside. They have no value when they are generated, this is changed by adding calculations to each construction assignment. Due to the way the polylines for tracing rooms were defined, the total thickness of the exterior wall is defined in  $\Delta_{din}$ . The interior walls' values  $\Delta_{din}$  and  $\Delta_{dout}$  are both calculated as half of the total thickness. When the calculations are applied, the construction thicknesses are visible in the 3D model when activating the offset settings in the *Geometry Viewer*. However, the direction of  $\Delta_{din}$  and  $\Delta_{dout}$  need to be checked in the *Geometry Viewer*, since the 3D Tool has troubles to automatically verify the right directions.

To assign rooms, volumes are selected separately but are linked in the same way as surfaces. New parameters are generated automatically as well, like the net floor area, gross floor area, volume, gross volume, etc. Also, all faces of the volume are referenced below the room's component. Next to each surface and volume, yellow symbols are marking components which are connected to the geometry. By clicking on them the interface jumps directly to the selected element in the *Geometry Viewer*.

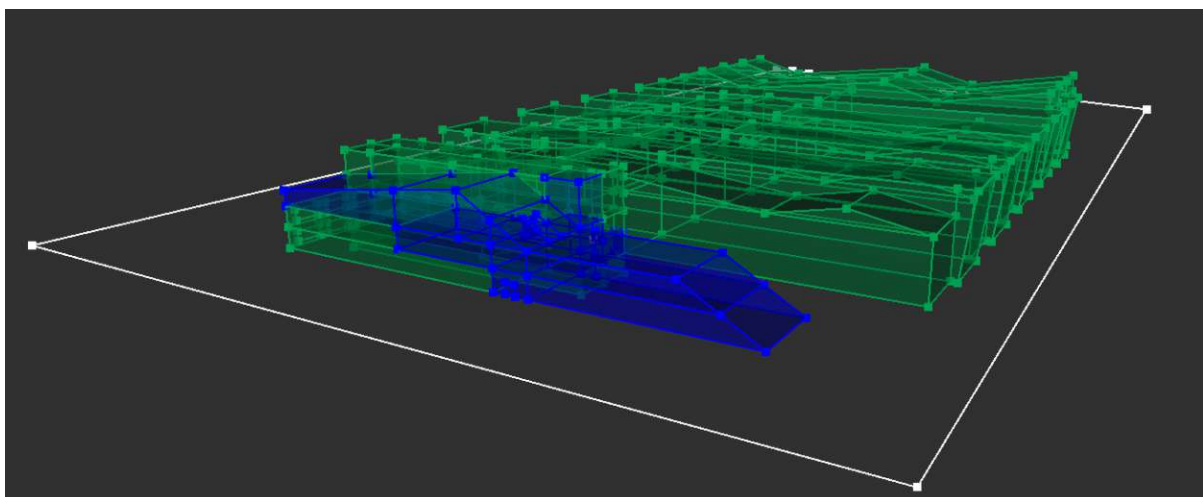


Figure 15: Visualisation of the geometrical model, consisting of vertices, edges, faces, and volumes. The office area is displayed in blue, the industrial area in green. The property boundary is modelled with white lines.

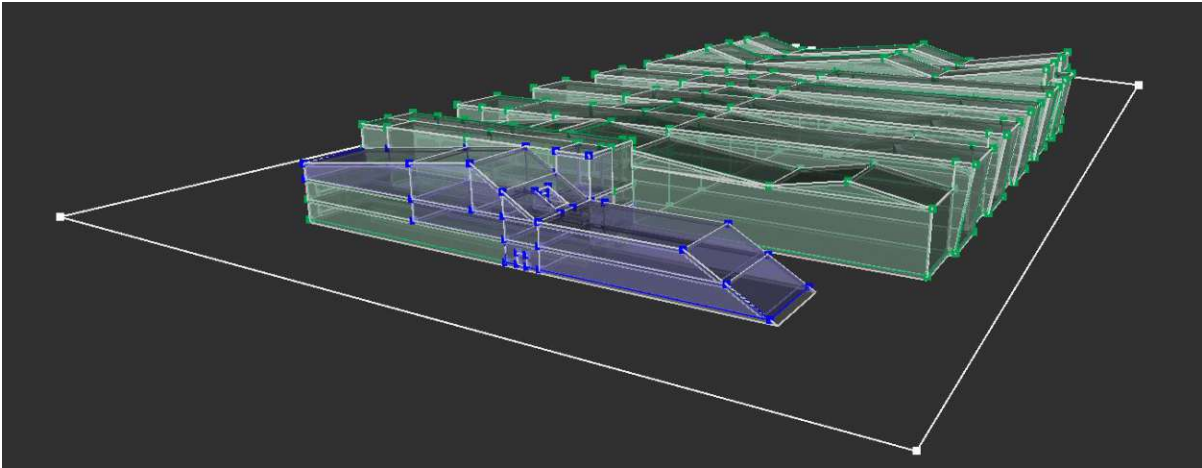


Figure 16: Visualisation of the geometrical model and the thickness of constructions

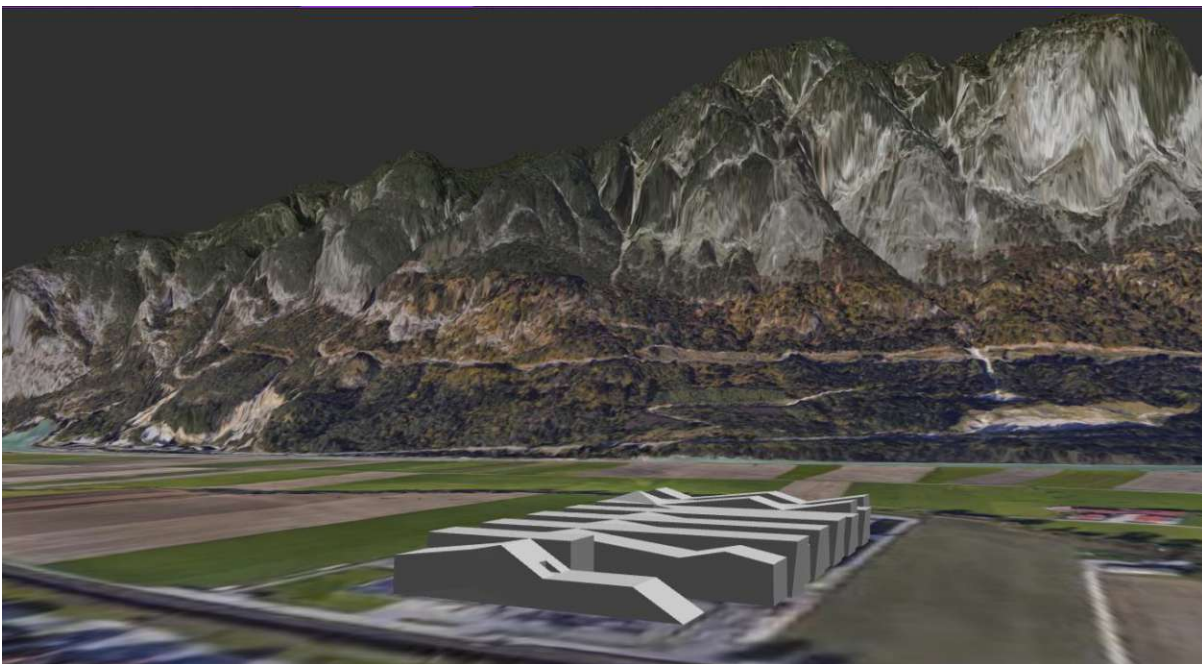


Figure 17: Visualisation of the 3D-Model with Surrounding

### *Building Utilisation and HVAC*

Since *SIMULTAN* offers no templates, also the utilisations profiles need to be prepared by the user. When creating these utilisations profiles expert's know-how would be an advantage, since *TopPhiCO2* is developed to generate more precise dynamic simulations of the overall building performance. These utilisation profiles are set up as detailed value fields that hold information for each 15 minutes for a week. This is done for all existing rooms. Then they are attached to parameters, which are later transferred to the *TopPhiCO2- Tool*.

For obtaining the two conditioned zones the rooms are referenced to the simulation-zone office or industrial and as a result grouped. The HVAC systems are much easier to prepare. Therefore, both

simulation-zones (office-zone and industrial-zone) get multiple parameters. These parameters are defined as equipment, heating, cooling, lighting, ventilation as well as persons and only hold the values of "yes" or "no". When exporting them to the Excel-Tools, the numeric values are already implemented in the *Excel-Validierungs-Tool*.

#### 5.1.2.2. Energy Performance Certificate in SIMULTAN

*SIMULTAN* is not able to generate EPCs directly, but since it is able to transfer its data to any Excel-Workbook by setting rules in the header "Tools" – the Excel-Tool Editor, the calculation can be performed in the external tool. In this thesis, the Excel-Workbook *TopPhiCO2\_FassungSIMULTAN\_90* is used. This tool is currently being developed and errors are still occurring. However, for the export the user needs to define rules for values of components, parameters, and value fields. Of course, the parameters that are assigned to a geometrical surface or volume of the Geometry Viewer can be used as well for the transfer to Excel. In this way, essential values of the geometrical model and the data model are delivered to Excel and are ready to be used for the simulation calculations.

For the transfer two sets of rules are used: one to deliver the topology and one to transfer the constructions, building services and utilisations. This process is error prone. Some problems are listed in an error sheet, but for the user it is not always easy to verify the source of the problems. Since the Excel-file performs the simulation by executing VBA code, knowledge about coding is needed to figure out and solve the problems. When all essential data is transferred, the simulation starts automatically. As mentioned in *Section 3.5*. the Excel-Workbook – the *Excel-Validierungs-Tool* – is utilised by *TopPhiCO2*. During the execution of *TopPhiCO2*, the *Excel-Validierungs-Tool* is automatically opened and calculates the conventional EPC. The result is written back to *TopPhiCO2* automatically and ends the whole operation. The results of EPC S.C. are demonstrated in the following *Table 12*. All abbreviations describe location-based values. The listed GFA and V are conditioned zones.

<i>EPC</i>	<i>Unit</i>	<i>Office Area</i>	<i>Industrial Area</i>
<i>GFA</i>	$m^2$	2.279,20	27.705,28
<i>V</i>	$m^3$	12.561,74	349.065,71
<i>HED</i>	$kWh/m^2a$	67,7	43,6
<i>PED</i>	$kWh/m^2a$	242,6	219,2
<i>EED</i>	$kWh/m^2a$	140,5	121,6
<i>CO<sub>2</sub></i>	$kg/m^2a$	20,1	24,1
<i>f</i>	-	0,76	0,27

Table 12: Results of the EPC S.C. – Office and Industrial Area

### 5.1.2.3. Occurring Problems

By testing the currently used workflow of the *SIMULTAN* developer team (Pascaleva & Steiner, 2020) with a multizone building, numerous steps were necessary as described in *Section 5.1.2.1*. The author provides an improved workflow from *ArchiCAD* to *SIMULTAN* to create EPCs. This workflow is valid for buildings in general – not only for this multizone facility. The improved workflow is supported by a guideline which is visualised in *Section 5.2.2.3*.

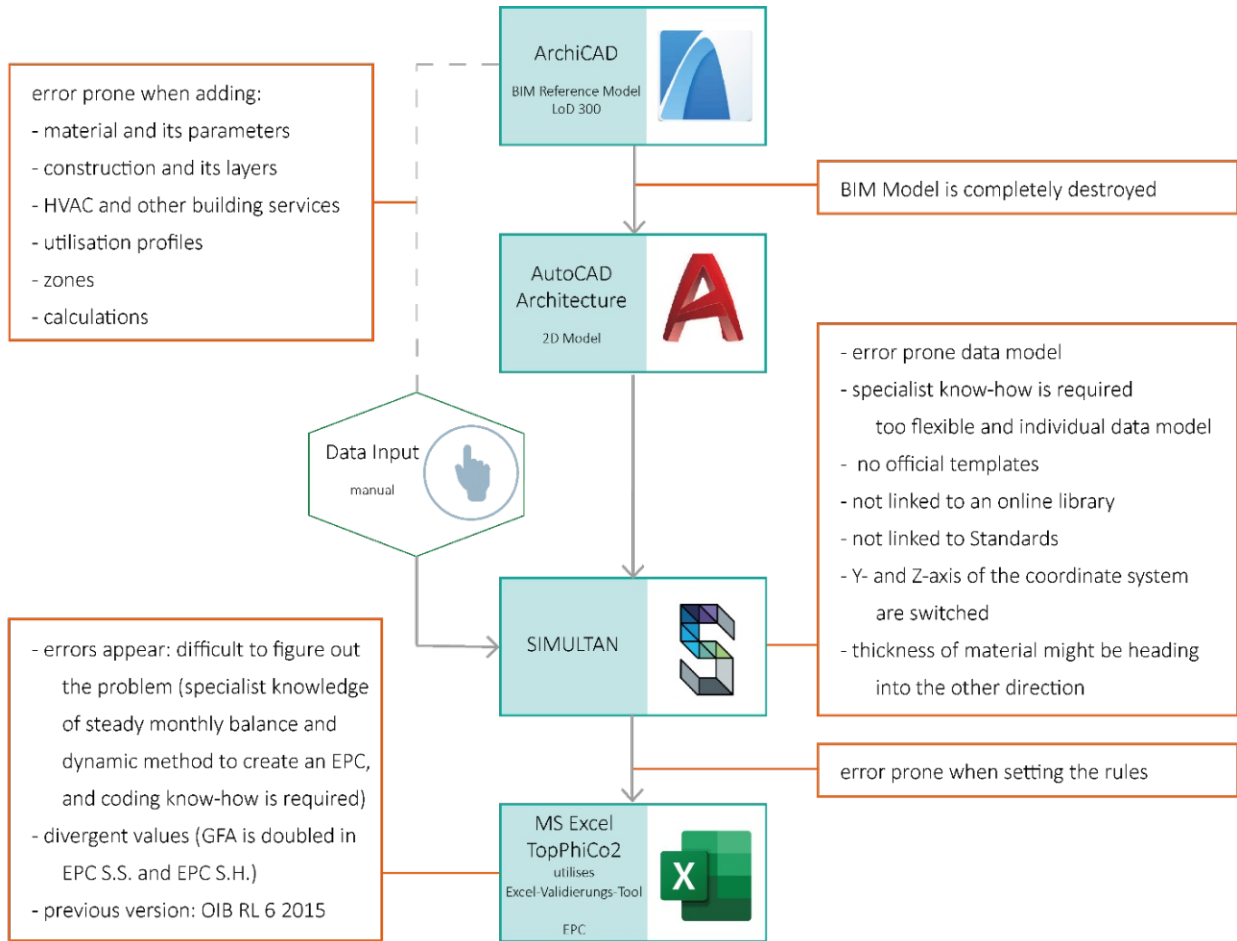


Figure 18: Visualisation of the occurring problems in the ArchiCAD to *SIMULTAN* Workflow for multizone buildings.

## 5.2. Improvement of Workflows - Variant 2: Standard Facade System

Both BIM to EPC workflows described in *Section 5.1.* have a lot of potential for improvement since numerous manual steps are necessary and various problems occur. For this reason, improved workflows are developed and guidelines are provided to make these BIM to EPC processes more efficient. In this section the improved workflows are tested and the EPC A.S. and EPC S.S. are generated in the end by using standard facade system. The standard as well as the high-end facade system were defined in a research study as part of a bachelor thesis of usually used elements for industrial buildings. The bachelor thesis “Last- und Aufbautenkatalog im österreichischen Industrie- und Gewerbebau“ by Christoph Appl was written at the Institute of Integrated Planning and Industrial Production at the Vienna University of Technology in 2020 (Appl, 2020).

The standard facade system used for EPC A.S. and EPC S.S. is listed in *Table 4.*

The interior constructions are the same in all variants and are listed in *Table 5.*

### 5.2.1. Improvement of ArchiCAD to ArchiPHYSIK Workflow

As described in *Section 5.1.1.*, there are a lot of troubles appearing that lead to the need of extreme simplification of the reference BIM model. After the unreasonably time-consuming pre-process of both zones, the architectural BIM model is significant destroyed and of no use anymore, except for the *ArchiPHYSIK* Add-On. The level of detail of the manipulated models is not higher than LoD100. Therefore, the author comes to the conclusion, even though using layer combinations to hide all unnecessary elements, this option still causes too many troubles. This happens especially when working with a multiple zone model, multilayer constructions, and intricate geometries.

The improved *ArchiCAD* to *ArchiPHYSIK* workflow is visualised in *Figure 19.*



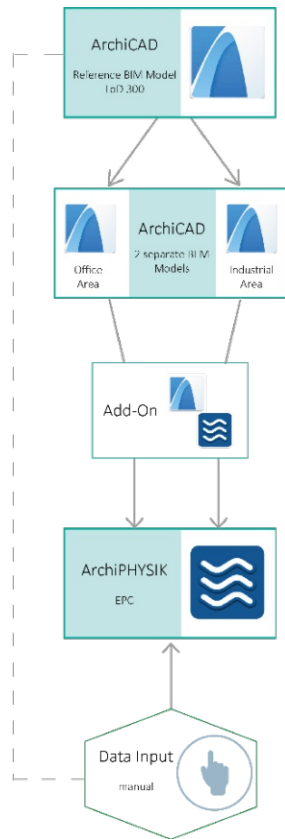


Figure 19: Improved ArchiCAD to ArchiPHYSIK Workflow for Multizone Buildings

#### 5.2.1.1. Transfer to ArchiPHYSIK

To improve this workflow, two separate BEM models with single-layer constructions in new Solo-projects are modelled. In this way, walls, roofs, ceilings, and bases are able to connect correctly. This is supposed to be much easier and faster than simplifying and remodelling the BIM model for the first zone and then doing this over again for the second one. By using this way of modelling a BEM model, the original BIM model LoD300 is not manipulated.

The office area is modelled first, because it is much smaller and has a simpler geometry than the hall and the pastry production area. Before starting modelling, all settings, including the facade system and other construction elements as single-layer elements and their names, are arranged. The glass facade is modelled as a normal wall to receive the right value of square meters. It is still essential to add the glass facade surfaces manually in the end. After finishing the office zone model, the exporter assistant of the Add-On is applied. When checking the transferred elements, one surface facing the south is missing. It concerns one wall that is trimmed by a roof situated below the wall. Except for this surface, everything else has arrived in *ArchiPHYSIK*. The roofs show no trouble in the new modelled office area BEM model. The Building Energy Model of the industrial area is modelled with monolithic elements as

well and instead of the glass facade a normal wall is used. The sloped walls are modelled straight to avoid receiving surfaces with 0 m<sup>2</sup>. In this way, the walls and roofs are also able to connect.

Finally, when both BEM models are finished and transferred from *ArchiCAD* to *ArchiPHYSIK* the post-process could start. This procedure includes verifying the imported surfaces and adding the lost ones manually. For example, most roof surfaces of the hall did not arrive in *ArchiPHYSIK*. To ensure all surfaces are verified, a feature in *ArchiCAD* is applied – the evaluation application. All elements that are hold in the project are visible with numbers and figures in this document, also showing in which floor they are situated. In this way, it becomes much easier to add the missing surfaces as well as the vertical glass facades of the roof. The following *Table 13* shows the elements which are not transferred and need to be added manually.

Office Area – Missing Elements						
Floor	Name of Layer	User ID	m <sup>2</sup>	Direction	Status	
Ground Floor	AW01_Glass Facade	Wand-001	145,13	South	Manually Added	
		Wand-003	125,95	North		
		Wand-005	46,24	East		
First Floor		Wand-010	195,84	South		
		Wand-013	102,68	North		
Second Floor		Wand-014	20,74	East		
		Wand-018	267,07	South		
		Wand-019	42,93	East		
		Wand-032	36,88	South		
Roof		Da01	Dach-001	79,63		East 30 Degrees
	Dach-002		79,63	East 30 Degrees		
	Dach-003		608,26	West 15 Degrees		
	Dach-004		204,28	East 30 Degrees		
Industry Hall Area - Missing Elements						
Floor	Name of Layer	User ID	Quantity	m <sup>2</sup>	Direction	Status
Ground Floor	AW01_Glass Facade	Wand-031		167,05	South	Manually Added
		Wand-054	5	27,68	North	
		Wand-056	5	27,68	South	
First Floor		Wand-014		25,37	East	
		Wand-047		92,92	South	
Second Floor		Wand-014		58	East	
		Wand-050		381,84	South	
		Wand-056	4	70,89	South	
		Wand-056	4	129,06	South	
		Wand-056	2	211,19	South	
		Wand-058	3	70,89	North	
		Wand-058	3	129,06	North	
Roof		Da01	Dach-005	5	1543,44	
	Dach-006			485,92	Horizontal	
	Dach-007		4	192,68	East 15 Degrees	
	Dach-007		4	192,68	West 15 Degrees	
	Dach-007			569,05	West 15 Degrees	
	Dach-007		4	570,12	East 15 Degrees	
	Dach-007		3	572,74	West 15 Degrees	

		Dach-009	2	201,34	West 30 Degrees	
		Dach-012	2	200,29	East 30 Degrees	
		Dach-013	2	555,35	West 30 Degrees	
		Dach-014	2	203,45	East 30 Degrees	
		Dach-015	2	387,14	West 30 Degrees	

Table 13: This list shows all surfaces that need to be added manually.

Floor Zones Office Area		ARCHICAD BEM MODEL Floor Zones in the Office Area		ARCHIPHYSIK Floor Zones in the Office Area	
Floor	Zone	Gross Floor Area [m <sup>2</sup> ]	Volume [m <sup>3</sup> ]	Gross Floor Area [m <sup>2</sup> ]	Volume [m <sup>3</sup> ]
0.Floor	Office GF	722,45	2.789,75	722,45	2.789,75
1.Floor	Office 1.F	909,8	3.539,15	909,8	3.539,15
2.Floor	Office 2.F	799,67	4.063,77	799,67	4.063,77
		<b>2.431,92</b>	<b>10.392,67</b>	<b>2.431,92</b>	<b>10.392,67</b>
Floor Zones Industry Area		ARCHICAD BEM MODEL		ARCHIPHYSIK	
Floor	Zone	Gross Floor Area [m <sup>2</sup> ]	Volume [m <sup>3</sup> ]	Gross Floor Area [m <sup>2</sup> ]	Volume [m <sup>3</sup> ]
Basement	MP Area B	769,66	3.078,63	769,66	3.078,63
0.Floor	MP Area GF1	1.380,22	5.520,88	1.380,22	5.520,87
0.Floor	MP Area GF2	16.513,63	257.272,39	16.513,63	25.727,39
1.Floor	MP Area 1.F	1.104,3	4.417,2	1.104,3	4.417,2
2.Floor	MP Area 2.F	705,92	5.647,32	705,92	5.647,32
		<b>20.473,73</b>	<b>275.936,41</b>	<b>20.473,73</b>	<b>275.936,41</b>

Table 14: GFA and volumes sizes of BEM Models in ArchiCAD and ArchiPHYSIK

### 5.2.1.2. Energy Performance Certificate in ArchiPHYSIK

To create the EPC A.S. all relevant additional data, as already mentioned in Section 5.1.1.1., needs to be filled in as well. After this, the EPC is generated. All abbreviations describe location-based values. The listed GFA and V are conditioned zones.

EPC	Unit	Office Area
GFA	m <sup>2</sup>	2.431,92
V	m <sup>3</sup>	10.392,66
HED	kWh/m <sup>2</sup> a	51,25
PED	kWh/m <sup>2</sup> a	196,60
EED	kWh/m <sup>2</sup> a	114,72
CO <sub>2</sub>	kg/m <sup>2</sup> a	32,53
f	-	0,74

Table 15: Results of the EPC A.S. – Office Area

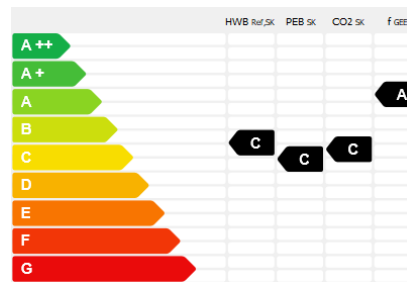


Figure 20: EPC Category Scale A-F - Office Area

EPC	Unit	Industrial Area
GFA	m <sup>2</sup>	20.473,73
V	m <sup>3</sup>	275.936,42
HED	kWh/m <sup>2</sup> a	59,72
PED	kWh/m <sup>2</sup> a	296,14
EED	kWh/m <sup>2</sup> a	175,18
CO <sub>2</sub>	kg/m <sup>2</sup> a	49,83
f	-	0,31

Table 16: Results of the EPC A.S. – Industrial Area

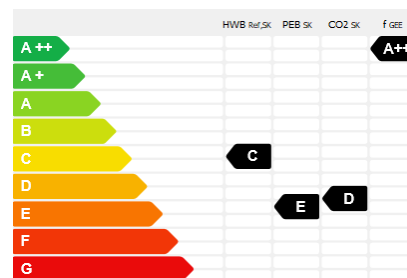


Figure 21: EPC Category Scale A-F - Industrial Area

### 5.2.1.3. Guideline for an ArchiCAD to ArchiPHYSIK Workflow for Multizone Buildings

This guideline is valid for all multizone buildings.

In the first step, the data model is transferred manually to *ArchiPHYSIK*. After this, the geometrical model needs to be pre-processed, then transferred, and at last post-processed.

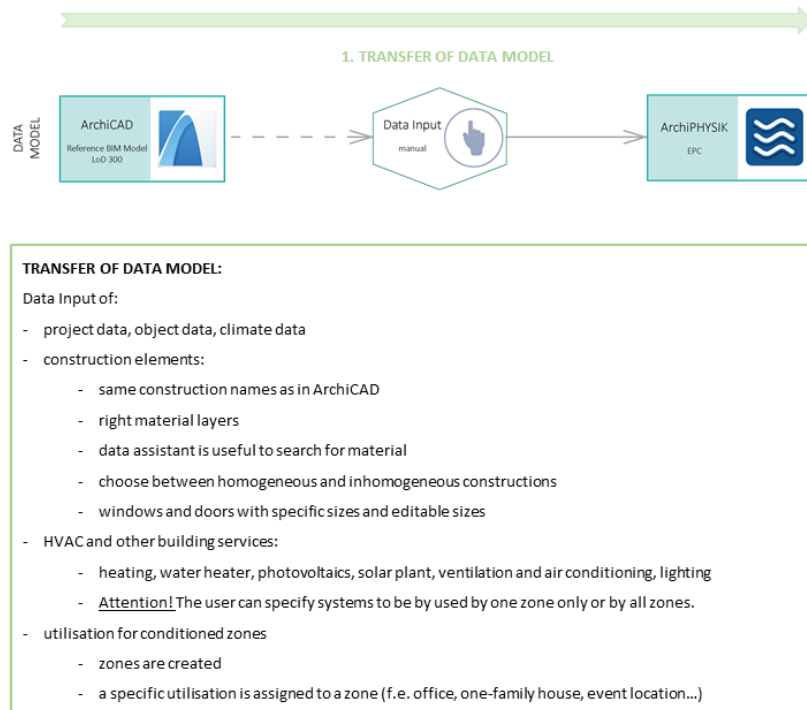


Figure 22: Guideline of transferring the data model of a Multizone Building from ArchiCAD to ArchiPHYSIK.

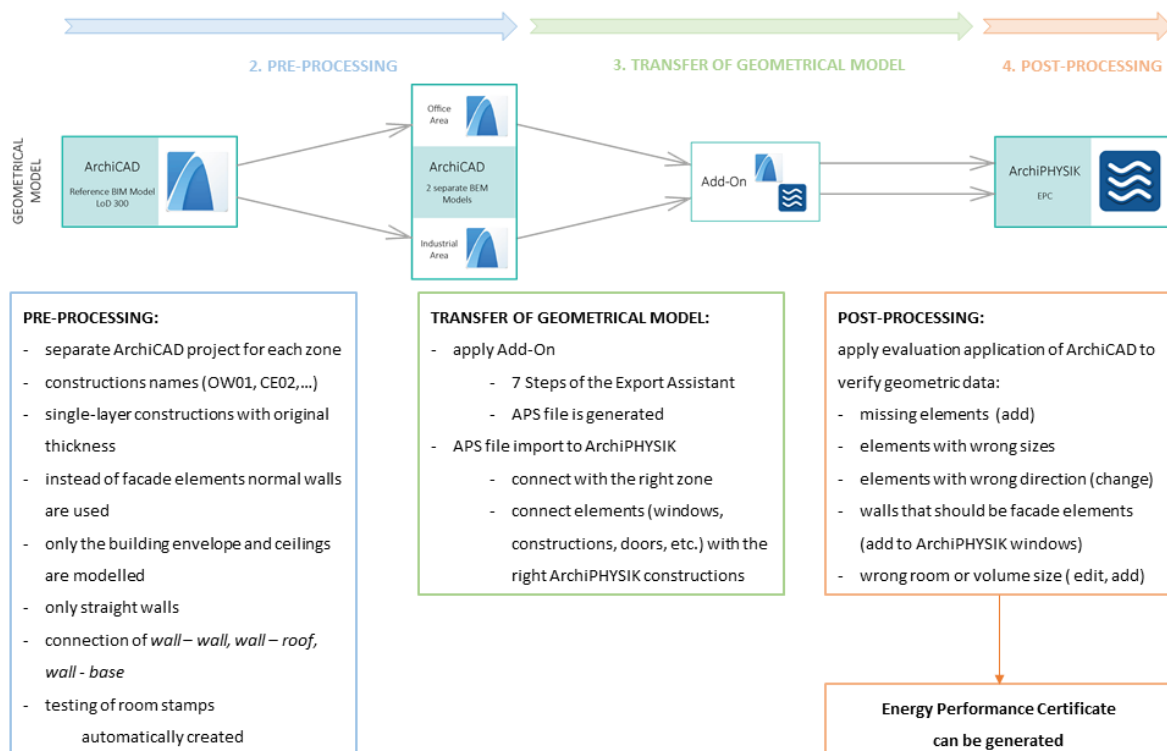


Figure 23: Guideline of transferring the geometrical model of a Multizone Building from ArchiCAD to ArchiPHYSIK.

## 5.2.2. Improvement of ArchiCAD to SIMULTAN Workflow

In *Section 5.1.2.*, the time-consuming procedure of creating elements is demonstrated. This includes looking up all the materials, creating material parameters, layers and constructions. Afterwards all the utilisation, building services, etc. are added. However, this whole procedure only has to be done at the very first time, due to the functionality of exporting and importing components, the parameters and the references can easily be transferred to another *SIMULTAN* project. The user obtains a big material and construction library after modelling and calculating some projects. In this section, it is assumed that the user already has those libraries. Templates and libraries are used, which are either created by the users themselves, or are provided by developers in ideal circumstances.

The improved *ArchiCAD* to *SIMULTAN* workflow is visualised in *Figure 24*.

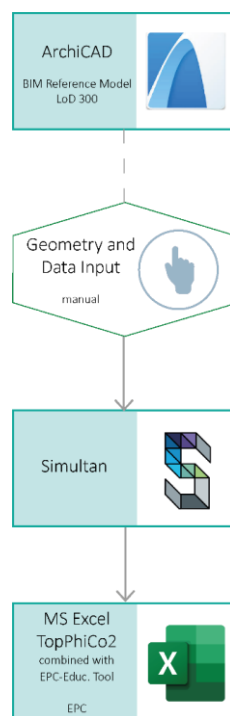


Figure 24: Improved ArchiCAD to SIMULTAN Workflow (for buildings without detailed room structures)

### 5.2.2.1. Transfer to SIMULTAN

#### Improvement without any Previous Projects and without Templates or Libraries

The major thing that can be improved in the case of not using templates or libraries is the modelling of the 3D building. The pre-process in *AutoCAD* is still time-consuming and has no advantage when looking at this specific project or at project with zone models (without detailed room structures). By connecting

the rooms to the required zones, the modelling of each room is unnecessary. If all rooms are required, the intermediate step in *AutoCAD* is still useful. But since the same conditions as in *ArchiPHYSIK* are required for the calculations, minimalistic models are defined. Therefore, the 3D model with two zones and fewer rooms becomes less complex. Considering this, modelling the building directly in the *Geometry Viewer* is faster, especially when the object sizes need to be measured manually in *ArchiCAD* during the process. For exactly this reason, in this case the building is modelled directly in the *Geometry Viewer* as the improved BIM to EPC Workflow is visualising in *Figure 24*. This seems to be the only improvement that can be suggested without templates or libraries.

#### *Improvement with Previous Projects or with Provided Templates and Libraries*

In addition to modelling the geometrical model directly in the *Geometry Viewer*, the data model can be reused for the second BIM to EPC workflow with *SIMULTAN*. In this way, the time can be shortened tremendously. Nevertheless, the reuse of a data model can be done as well in any other *SIMULTAN* project. Either the whole data model or only parts of it can be transferred.

In the first step of creating a data model in this use case, only the material components and their specific property parameters are imported. By reusing only the material library a lot of time can be saved already. Of course, new materials need to be added, but fortunately not all. Constructions also need to be created by adding layers, calculation, etc. For cutting this step short, one construction of the previous project can be imported for using it as a template. Window and curtain wall (glass facade) components are likewise convenient to be transferred from another project. Not only components and parameters can be imported, but value fields as well. In this case, tables of the utilisation profile are reused. When a parameter to which a value field is attached is being transferred, the value field is imported to the new project automatically and is still connected. Additionally, the EPC-Zones, Sim-Zones, building services, etc. components are imported to the new project as well.

Moreover, at present, there are no templates provided when creating a new project. Additionally, not only the data model can be transferred, but also the geometrical model. Unfortunately, none of the assigned components are attached to the geometry after the import anymore.

### 5.2.2.2. Energy Performance Certificate in SIMULTAN

In the header “Tools” the export rules for the topology and the *TopPhiCO2* Tool are added, and components are assigned to the rules as described in *Section 5.1.2.2*. Then the export to the Excel-Tool can be started. The results of EPC S.S. are demonstrated in the following *Table 17*. All abbreviations describe location-based values. The listed GFA and V are conditioned zones.

EPC	Unit	Office Area	Industrial Area
GFA	m <sup>2</sup>	2.269,33	42.470,27
V	m <sup>3</sup>	12.159,09	355.104,90
HED	kWh/m <sup>2</sup> a	94,4	48,8
PED	kWh/m <sup>2</sup> a	260,8	228,5
EED	kWh/m <sup>2</sup> a	151,8	127,2
CO <sub>2</sub>	kg/m <sup>2</sup> a	20,7	24,6
f	-	0,81	0,44

Table 17: Results of the EPC S.S. – Office and Industrial Area

### 5.2.2.3. Guideline for an ArchiCAD to SIMULTAN Workflow

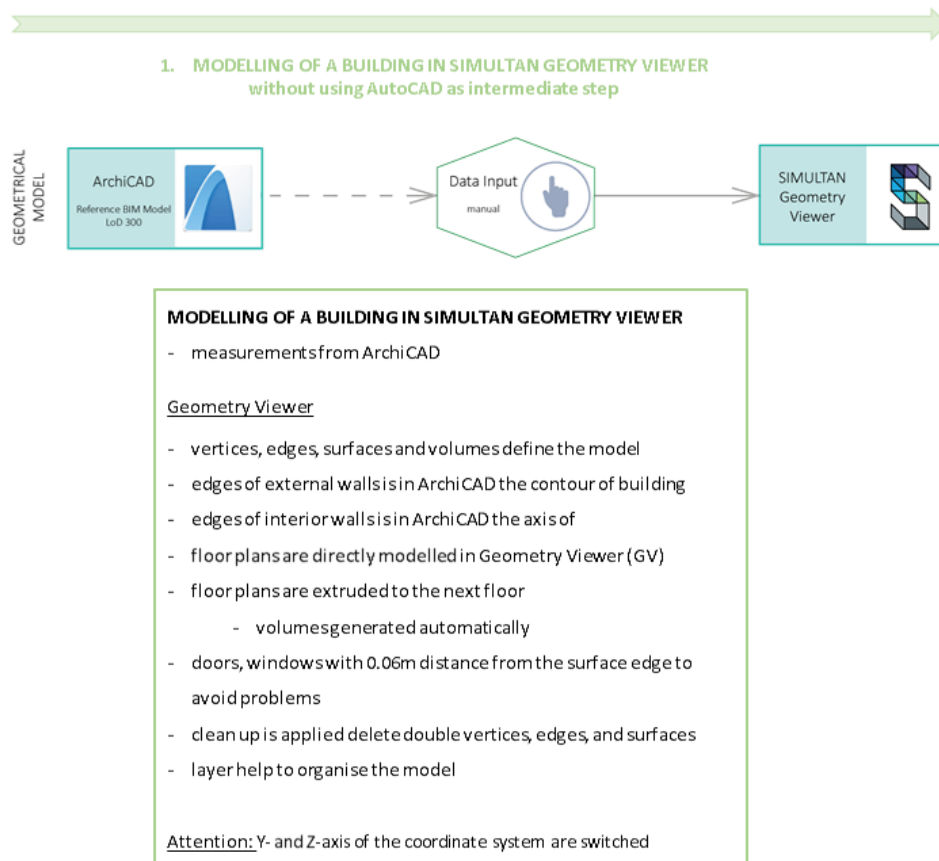


Figure 25: Guideline of transferring the geometrical model of buildings without detailed room structures and in this Thesis a Multizone Building from ArchiCAD to SIMULTAN

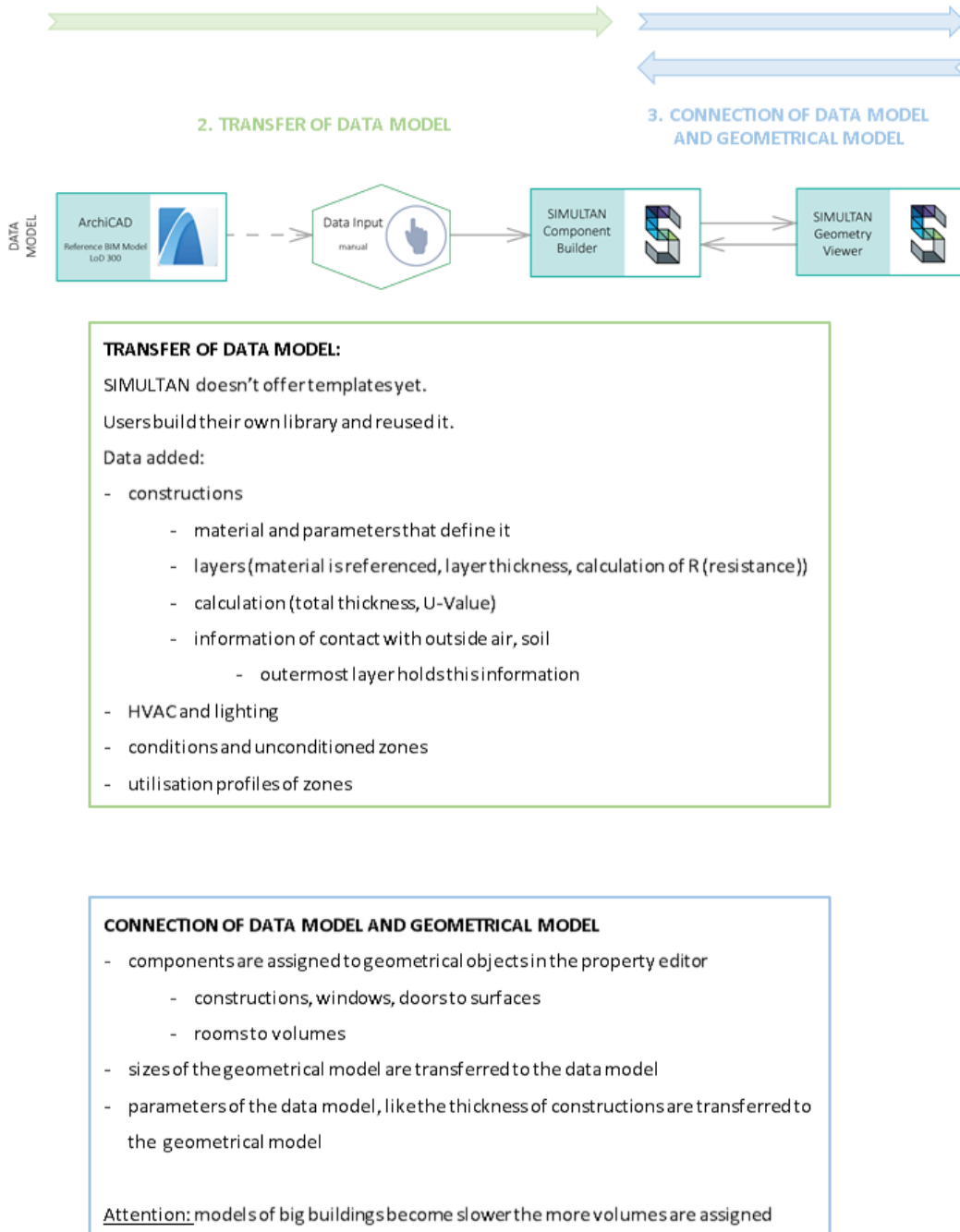


Figure 26: Guideline of transferring the data model from ArchiCAD to SIMULTAN.



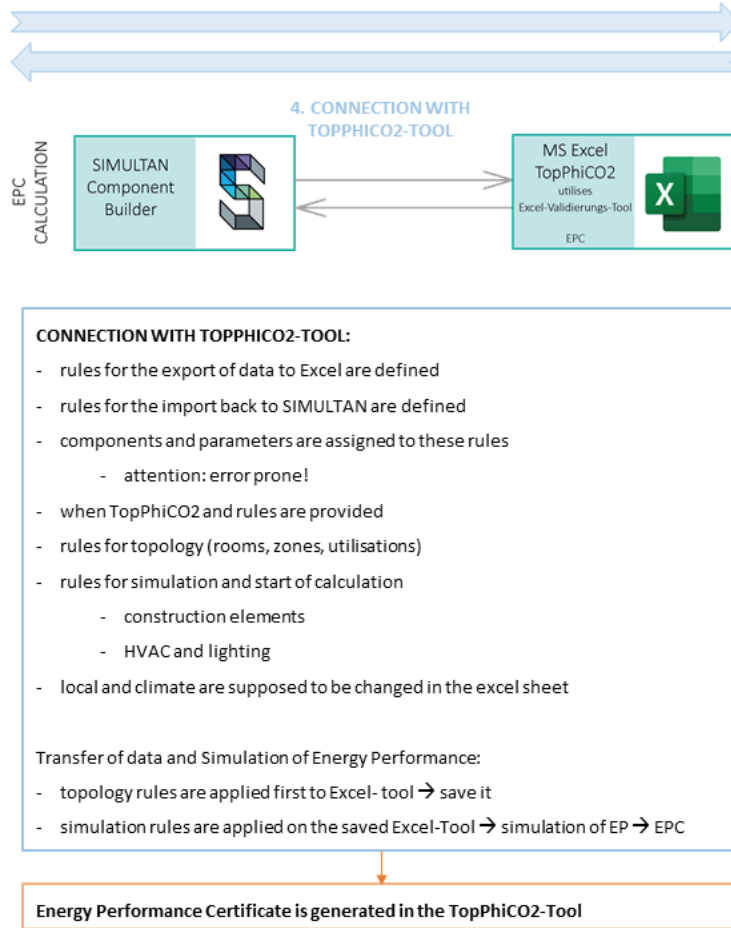


Figure 27: Guideline of transferring the data model of SIMULTAN to TopPhiCO2

### 5.3. Replacement of Facade System - Variant 3: High-End Facade System

To obtain the third EPC in ArchiPHYSIK, the facade system is changed directly in the EP Tools. The author has decided to change only the building envelope, neither the floor slabs inside the building, nor the interior walls, even when they divide the zones due to the negligible impact of these changes.

The high-end facade system used for EPC A.H. and EPC S.H. is listed in *Table 4*.

The interior constructions are the same in all variants and are listed in *Table 5*.

#### 5.3.1. Replacement of Facade System in ArchiPHYSIK

The most time efficient way to generate variants is duplicating the project and changing the existing constructions. Changing the elements works exactly like creating them by using the data assistant with the linked online material libraries, as explained in *Section 5.1.1.1*. This leads to following EPC A.H. results displayed in *Table 18*, *Table 19*, *Figure 28*, and *Figure 29*. All abbreviations describe location-based values. The listed GFA and V are conditioned zones.

EPC	Unit	Office Area
GFA	m <sup>2</sup>	2.431,92
V	m <sup>3</sup>	10.392,66
HED	kWh/m <sup>2</sup> a	50,53
PED	kWh/m <sup>2</sup> a	195,43
EED	kWh/m <sup>2</sup> a	113,96
CO <sub>2</sub>	kg/m <sup>2</sup> a	32,31
f	-	0,739

Table 18: Results of the EPC A.H. – Office Area

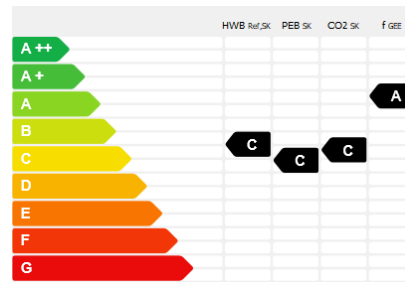


Figure 28: EPC Category Scale A.H - Office Area

EPC	Unit	Industrial Area
GFA	m <sup>2</sup>	20.473,73
V	m <sup>3</sup>	275.936,42
HED	kWh/m <sup>2</sup> a	75,16
PED	kWh/m <sup>2</sup> a	301,36
EED	kWh/m <sup>2</sup> a	178,61
CO <sub>2</sub>	kg/m <sup>2</sup> a	50,83
f	-	0,317

Table 19: Results of the EPC A.H. – Industrial Area

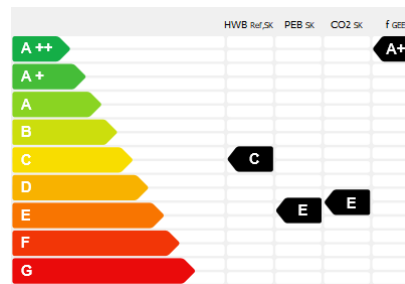


Figure 29: EPC Category Scale A.H - Industrial Area

### 5.3.2. Change of Facade System in SIMULTAN

Changing facade system in *SIMULTAN* is a very simple and intuitive process compared to the steps of creating a new project from the very start. New materials are created if needed, then layers to the constructions are added— as described in *Section 5.1.2*. Due to using construction assignments, the user does not have to link surfaces to the constructions again. This is done easily in the *Component Builder* by deleting the references of the old constructions and referencing the new one instead. The user has to recalculate the model by pressing the “calculate” button in the header to activate the current constructions’ properties. After this, the Excel-Tool *TopPhiCO2* can be reapplied. The new data is transferred to the Excel-sheet, including the values of the EPC of the high-end facade system. The energy values are delivered back to *SIMULTAN*. Additionally, the sheet is saved as EPC S.H. and uploaded into the *SIMULTAN* Project Explorer next to EPC S.C. and EPC S.S.

The results of EPC S.H. are demonstrated in the following *Table 20*. All abbreviations describe location-based values. The listed GFA and V are conditioned zones.

<i>EPC</i>	<i>Unit</i>	<i>Office Area</i>	<i>Industrial Area</i>
<i>GFA</i>	$m^2$	1.512,29	43.470,27
<i>V</i>	$m^3$	11.710,01	347.086,54
<i>HED</i>	$kWh/m^2a$	11,7	46,9
<i>PED</i>	$kWh/m^2a$	288,3	226,0
<i>EED</i>	$kWh/m^2a$	169,0	125,6
<i>CO<sub>2</sub></i>	$kg/m^2a$	21,6	24,6
<i>f</i>	-	0,65	0,44

*Table 20: Results of the EPC S.H. – Office and Industrial Area*

## 6. Results Comparison and Discussion

In the process of testing and improving the BIM to EPC workflows (A and S) of a multizone building in *Chapter 5.*, a variant study was created by applying three different facade systems (customised, standard, and high-end). In this part of the thesis, the results of the impact on the overall energy performance of the buildings are demonstrated in different aspects, compared, and interpreted.

### 6.1. Comparison of Gross Floor Area and Volume

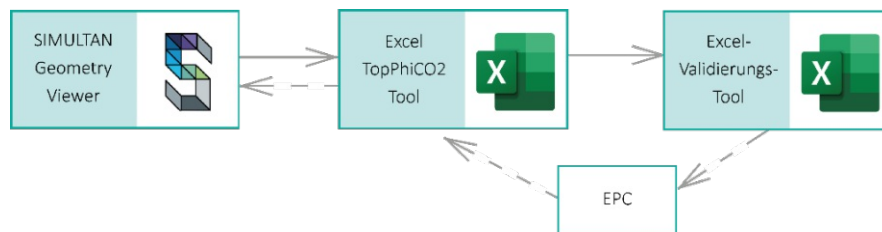
The tested and the improved BIM to EPC workflows of a multizone building operate in different ways as described in the previous chapter, but the results of the data and geometry should not differ significantly from the reference building. The fundamental geometrical values of the data transfer are the gross floor area (GFA) and the volume (V). In *Section 6.2.*, the EPCs results are compared and interpreted, but before this can be done accurately, the values – GFA [m<sup>2</sup>] and V [m<sup>3</sup>] – need to be compared based on the reference BIM model as well as the obtained results of *ArchiPHYSIK* and *SIMULTAN*. The values are directly visible in both EP Tools and not in the EPC results. The comparison of GFA and V of the conditioned zones is demonstrated in the following *Table 21*:

		ArchiCAD BIM Reference Object	ArchiPHYSIK Workflow A	SIMULTAN Workflow S
<b>Testing of Workflow (EPC A.C. &amp; S.C.)</b>				
Office GFA	m <sup>2</sup>	2.421,16 100%	2.426,93 0,23%	2.513,88 3,83%
Office V	m <sup>3</sup>	10.591,13 100%	9407,2 -11,18%	11.330,53 6,98%
Industry GFA	m <sup>2</sup>	19.932,26 100%	19.953,19 0,11%	19.963,43 0,16%
Industry V	m <sup>3</sup>	277.464,16 100%	257.609,57 -7,16%	286.416,97 3,23%
<b>Improvement of Workflow (EPC A.S. &amp; EPC S.S.) &amp; Change of Facade System (EPC A.H. &amp; EPC S.H.)</b>				
Office GFA	m <sup>2</sup>	2.421,16 100%	2.431,92 0,44%	2.416,47 -0,20%
Office V	m <sup>3</sup>	10.591,13 100%	10.392,66 -1,87%	10.695,12 0,98%
Industry GFA	m <sup>2</sup>	19.932,26 100%	20.473,73 2,72%	20.154,13 1,11%
Industry V	m <sup>3</sup>	277.464,16 100%	275.936,42 -0,55%	286.842,91 3,38%

Table 21: Diverging results of GFA and V after the transfer of the geometrical model. Values are taken directly from the Energy Performance Tools.

In both EP Tools deviations occur, especially in the firstly tested workflows. In the case of workflow A this is due to the occurred errors during pre-processing, where the BIM model was remodelled to a BEM model. This procedure of manipulating needed to be done multiple times to finally transfer the data via the Add-On to *ArchiPHYSIK*. Especially the remodelling of the second BEM model changed the results. However, fortunately the differing values of more than -7,00% appear only in the volumes and not the gross floor area. In Workflow S the notable difference is also in the volumes. The volumes have a higher difference due to the manual modelling of the sloping roof surfaces. In case of the tested workflow, the deviations of the office area GFA of 3,83%, the office area V of 6,98%, and the industrial area V of 3,23% are probably caused by the intermediate step by using *AutoCAD* as well as the transfer via DXF-file for pre-processing. Interesting enough, the GFA of the office area of the first *SIMULTAN* workflow is higher than in the second one, but in the industrial area it is exactly the opposite.

Due to the VBA-code of *TopPhiCO2*, another data transfer is performed during the calculation of the EPCs. During this transfer, all values obtain divergences from -37,42% to -6,09% and 9,49% to 115, 69%, which are clearly too high. This leads to the conclusion that the Excel-Workbook *TopPhiCO2* (effective version: *TopPhiCO2\_FassungSIMULTAN\_90*) has either problems with the data transfer, certain calculation issues in the workbook itself, or during the utilisation of the *Excel-Validierungs-Tool* wrong values are used and written back, as visualised in *Figure 30*.



*Figure 30: Process from SIMULTAN to the TopPhiCO2 Excel-workbook which is utilising the Excel-Validierungs-Tool and writes back the EPC results to TopPhiCO2.*

Since the difference of the values are that high, the results were examined more closely, which are displayed in the EPCs and can be found in the appendix of this thesis. For some values it is unclear why specific values are taken, since they describe other areas or volumes - just as the GFA of 2 279m<sup>2</sup> of the office area in EPC S.C., which is also demonstrated in *Table 22*. That particular GFA uses mistakenly the sum of all construction elements of the conditioned office area that are in contact with outdoor air - this value is visible in *TopPhiCO2* in the preparation sheet. Therefore, the net floor area (NFA) was calculated by multiplying the GFA by 0,8, which would be accurate in general, yet obviously generates wrong values in this case. Furthermore, this wrong NFA was wrongly used as value of the building envelope area as well. However, for some values it is impossible to verify how they are calculated. Also, the obtainment of the gross volume is not transparent. Therefore, basically all values that are displayed

in the EPCs of *SIMULTAN* are questionable. The volumes of the industrial area in the EPC S.S. and EPC S.H. of *TopPhiCO2*, shown in *Table 22*, are especially curious since the values simply doubled. The office area of EPC S.H. of *TopPhiCO2* is 1 512m<sup>2</sup> has a much smaller value (-37,42%), although the same Excel *TopPhiCO2-worksheet* was used.

Consequentially, the transfer of the data from *SIMULTAN* to the Excel-Tools should be corrected. As mentioned, *SIMULTAN* and its tools are still in development and mistakes are more likely to occur.

		SIMULTAN	TopPhiCO2 – EPC	
		Customised Facade System	Customised Facade System	
Office GFA	m <sup>2</sup>	2 513 100%	2 279 -9,34%	
Office V	m <sup>3</sup>	11 330 100%	12 561 10,87%	
Industry GFA	m <sup>2</sup>	19 963 100%	27 705 38,78%	
Industry V	m <sup>3</sup>	286 416 100%	349 065 21,87%	
		Standard and High-End Facade System	Standard Facade System	High-End Facade System
Office GFA	m <sup>2</sup>	2 416 100%	2 269 -6,09%	1 512 -37,42%
Office V	m <sup>3</sup>	10 695 100%	12 159 13,69%	11 710 9,49%
Industry GFA	m <sup>2</sup>	20 154 100%	42 470 110,73%	43 470 115,69%
Industry V	m <sup>3</sup>	286 842 100%	355 104 23,80%	347 086 21,00%

*Table 22: Difference of GFA[m<sup>2</sup>] and V[m<sup>3</sup>] of conditioned zones after the data transfer to TopPhiCO2 - EPC.*

In *Figure 31* all EPC results of the gross floor area and the volume of the office area are demonstrated to visualise divergences even better. Generally, it was expected that the values of the volumes differ, due to the roof shapes. Yet, this diagram makes it obvious that the values differ significantly between *ArchiPHYSIK* and *SIMULTAN*. Anyway, it is quite interesting that in the whole variant study all volumes generated in *ArchiPHYSIK* are smaller and at the same time all volumes of *SIMULTAN* are higher than the one of the reference building in *ArchiCAD*. In *Figure 32* it is clearly displayed that the GFA of the industrial area is calculated wrong and therefore much higher than in the reference object.

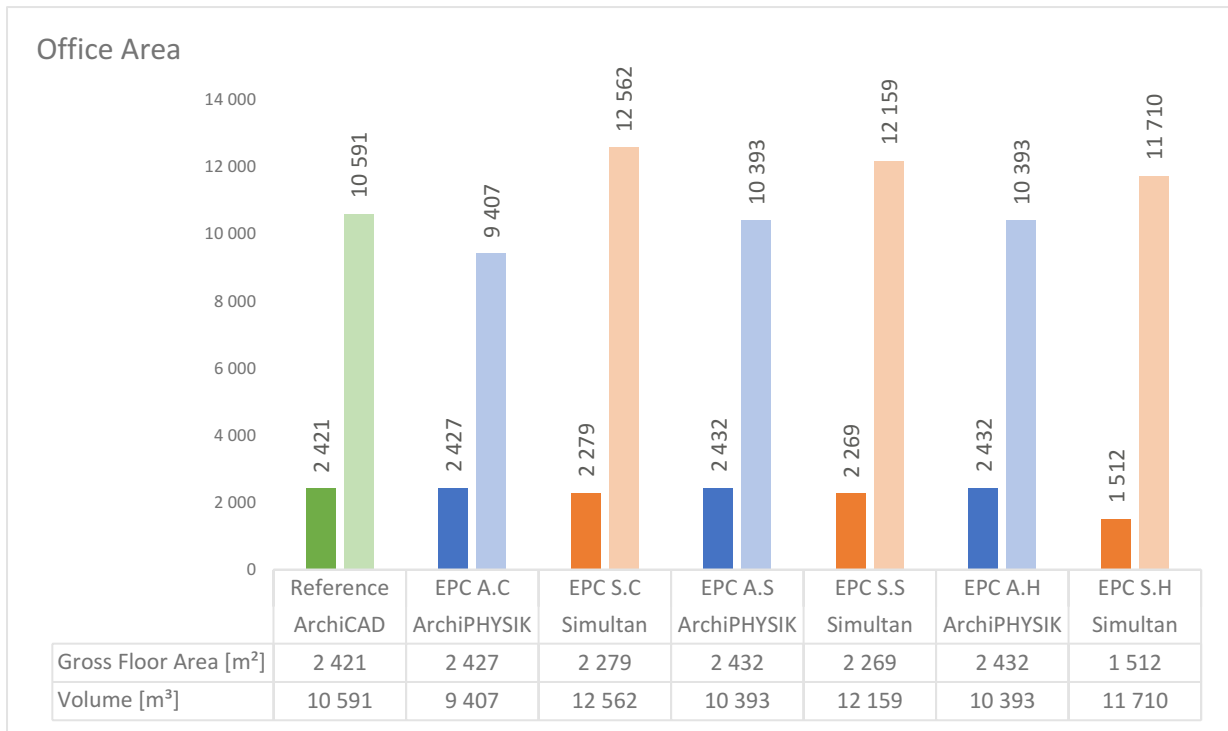


Figure 31: Difference of GFA[m<sup>2</sup>] and V[m<sup>3</sup>] of conditioned zones in all variants of the office area.

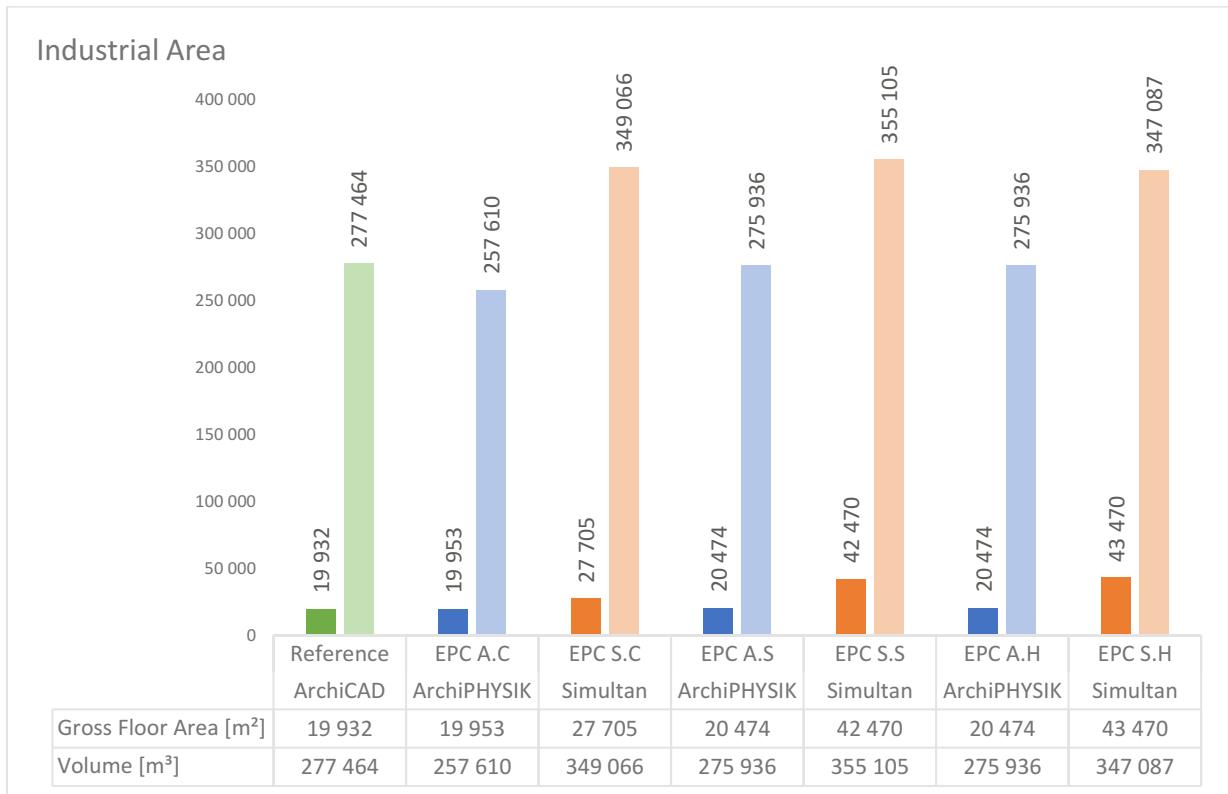


Figure 32: Difference of GFA[m<sup>2</sup>] and V[m<sup>3</sup>] of conditioned zones in all variants of the industrial area.

## 6.2. Results of the Variant Study

The variant study is created by using three different facade systems as listed in *Table 4*. The results are compared in the following *Figure 33 to Figure 38* and *Table 23 to Table 26*.

Although the results generated by *SIMULTAN* are not fully reliable, owing to the reasons mentioned above, the divergences of the variants regarding energy efficiency are visible. In this case, it is still more advisable to look at the more reliable results of *ArchiPHYSIK*. In addition to the results, the utilisations of the zones also differ from *ArchiPHYSIK* to *SIMULTAN* caused by the dynamic profiles that are needed for the calculation in *SIMULTAN*. In contrast to the steady monthly profiles of *ArchiPHYSIK*, where the utilisation is already implemented in the software, at present in *SIMULTAN* the users have to create utilisation profiles based on values for each 15 minutes for a week. This detailed way of calculation is due to the originally used dynamic method to obtain a dynamic energy performance simulation of a building in *TopPhiCO2*.

Furthermore, the EPC results of both conditioned zones display that the customised facade system are more efficient than the other ones. This can be traced to the higher U-Values. In the beginning the author expected the high-end variant to operate with more insulation, since high-end facade system are assumed to be more expensive. In this case, the standard and the high-end facade system have almost the same results considering the office area. Yet, the standard facade system has slightly better EPC results than the high-end in the industrial area, due to lower U-Values of the exterior wall and the roof, which is caused by thicker layers of insulation. To obtain even better results, more insulation can be added as well as energy-efficient systems like heat recovery, which would be a logical measure in case of an industrial bakery. In addition to these measures, solar panels would be advisable since the sloped roof surfaces provide ideal conditions. In this special type of building, it might be possible to recover the heat and provide it as district heating for the surrounding residential area.

It is quite interesting that the doubled GFA in EPC S.S. and EPC S.H. have no distinctive impact on the results.



## OFFICE AREA

All abbreviations describe location-based values and are based on GFA and V of the conditioned zones.

### Customised Facade System

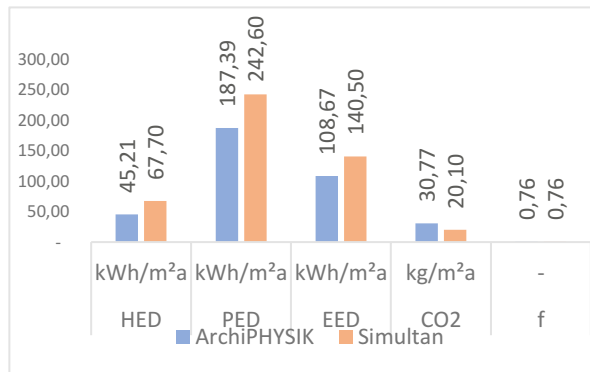


Figure 33: Energy Performance Results of the Office Area of EPC A.C. and EPC S.C.

### Standard Facade System

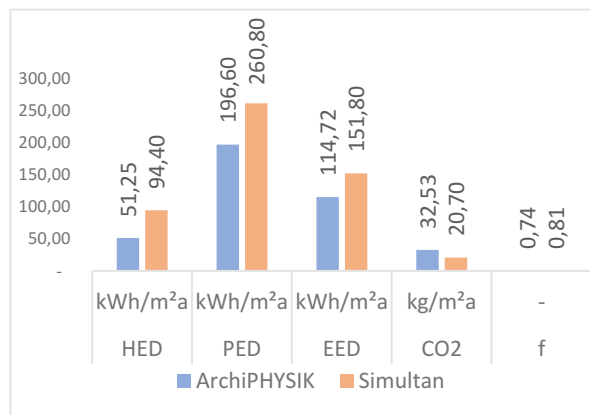


Figure 34: Energy Performance Results of the Office Area of EPC A.S. and EPC S.S.

### High-End Facade System

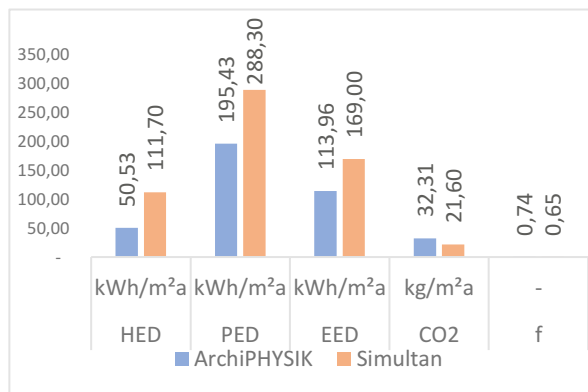


Figure 35: Energy Performance Results of the Office Area of EPC A.H. and EPC S.H.

## INDUSTRIAL AREA

### Customised Facade System

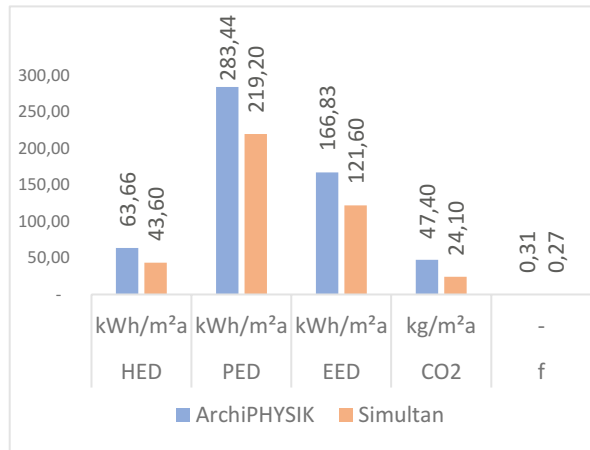


Figure 36: Energy Performance Results of the Industrial Area of EPC A.C. and EPC S.C.

### Standard Facade System

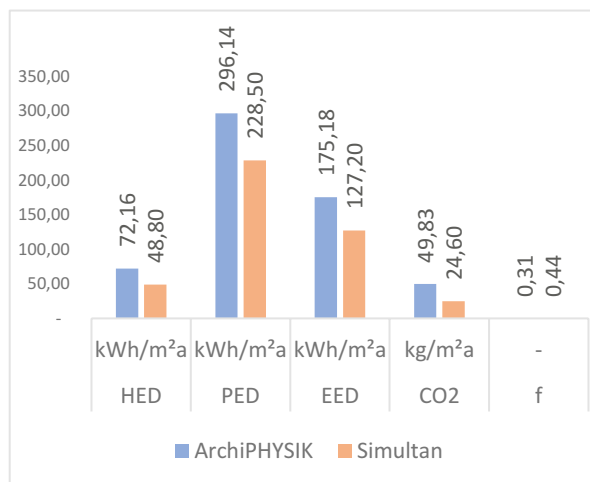


Figure 37: Energy Performance Results of the Industrial Area of EPC A.S. and EPC S.S.

### High-End Facade System

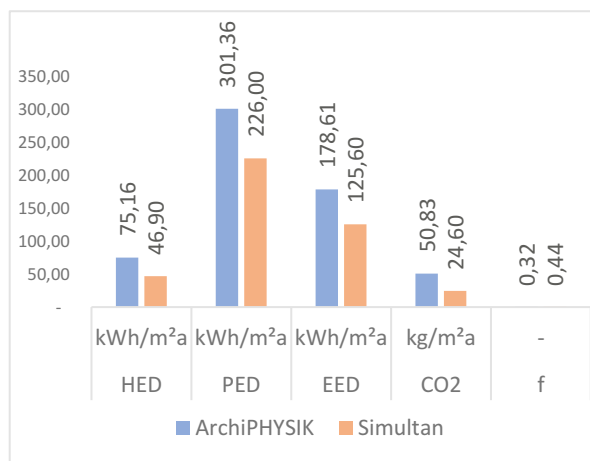


Figure 38: Energy Performance Results of the Industrial Area of EPC A.H. and EPC S.H.

In the *Table 23* to *Table 26* the variant study is represented by comparing the results of the same software by numbers and the divergences in percent.

#### OFFICE AREA ArchiPHYSIK

	Unit	Variant 1 EPC A.C.	Variant 2 EPC A.S.	Variant 3 EPC A.H.
GFA	m <sup>2</sup>	2426,93 100%	2431,92 +0,21%	2431,92 +0,21%
V	m <sup>3</sup>	9407,2 100%	10392,66 +10,48%	10392,66 +10,48%
HED	kWh/m <sup>2</sup> a	45,21 100%	51,25 +13,36%	50,53 +11,77%
PED	kWh/m <sup>2</sup> a	187,39 100%	196,6 +4,91%	195,43 +4,29%
EED	kWh/m <sup>2</sup> a	108,67 100%	114,72 +5,57%	113,96 +4,87%
CO <sub>2</sub>	kg/m <sup>2</sup> a	30,77 100%	32,53 +5,72%	32,31 +5,00%
F	-	0,763 100%	0,74 -3,01%	0,739 -3,15%

Table 23: Results of ArchiPHYSIK based on the Assessment of the Office Area of EPC A.C., EPC A.S. and EPC A.H.

#### OFFICE AREA SIMULTAN

	Unit	Variant 1 EPC S.C.	Variant 2 EPC S.S.	Variant 3 EPC S.H.
GFA	m <sup>2</sup>	2279,2 100%	2269,33 -0,43%	1512,29 -33,65%
V	m <sup>3</sup>	12561,74 100%	12159,09 -3,21%	11710,01 -6,78%
HED	kWh/m <sup>2</sup> a	67,7 100%	94,4 +39,44%	111,7 +64,99%
PED	kWh/m <sup>2</sup> a	242,6 100%	260,8 +7,50%	288,3 +18,84%
EED	kWh/m <sup>2</sup> a	140,5 100%	151,8 +8,04%	169 +20,28%
CO <sub>2</sub>	kg/m <sup>2</sup> a	20,1 100%	20,7 +2,99%	21,6 +7,46%
F	-	0,76 100%	0,81 +6,58%	0,65 -14,47%

Table 24: Results of SIMULTAN based on the Assessment of the Office Area of EPC S.C., EPC S.S. and EPC S.H.

INDUSTRIAL AREA - ArchiPHYSIK

	Unit	Variant 1 EPC A.C.	Variant 2 EPC A.S.	Variant 3 EPC A.H.
GFA	m <sup>2</sup>	19953,19 100%	20473,73 2,61%	20473,73 2,61%
V	m <sup>3</sup>	257609,57 100%	275936,42 7,11%	275936,42 7,11%
HED	kWh/m <sup>2</sup> a	63,66 100%	72,16 -13,35%	75,16 18,06%
PED	kWh/m <sup>2</sup> a	283,44 100%	296,14 4,48%	301,36 6,32%
EED	kWh/m <sup>2</sup> a	166,83 100%	175,18 5,01%	178,61 7,06%
CO <sub>2</sub>	kg/m <sup>2</sup> a	47,4 100%	49,83 5,13%	50,83 7,24%
F	-	0,306 100%	0,31 1,31%	0,317 3,59%

Table 25: Results of ArchiPHYSIK based on the Assessment of the Industrial Area of EPC A.C., EPC A.S. and EPC A.H.

INDUSTRIAL AREA - SIMULTAN

	Unit	Variant 1 EPC S.C.	Variant 2 EPC S.S.	Variant 3 EPC S.H.
GFA	m <sup>2</sup>	27705,28 100%	42470,27 53,29%	43470,27 56,90%
V	m <sup>3</sup>	349065,71 100%	355104,9 1,73%	347086,54 -0,57%
HED	kWh/m <sup>2</sup> a	43,6 100%	48,8 11,93%	46,9 7,57%
PED	kWh/m <sup>2</sup> a	219,2 100%	228,5 4,24%	226 3,10%
EED	kWh/m <sup>2</sup> a	121,6 100%	127,2 4,61%	125,6 3,29%
CO <sub>2</sub>	kg/m <sup>2</sup> a	24,1 100%	24,6 2,07%	24,6 2,07%
F	-	0,27 100%	0,44 62,96%	0,44 62,96%

Table 26: Results of SIMULTAN based on the Assessment of the Industrial Area of EPC S.C., EPC S.S. and EPC S.H.

## 7. Conclusion and Future Outlook

For improving the design process of energy-efficient buildings two open BIM to EPC workflows were tested, evaluated, and improved in this thesis. The main aim of this thesis is to reduce data loss and save time in pre- and post-processing within BIM to EPC workflows. Therefore, based on the evaluation results two improved workflows (ArchiCAD to ArchiPHYSIK and ArchiCAD to SIMULTAN) are developed and guidelines provided to make the creation of EPC variant studies at early design stages more efficient and reduce data loss. In the variant study the impact assessment of three different facade systems (customised, standard, high-end) to an overall energy performance of an industrial building is evaluated.

### 7.1. Building Information Model to Energy Performance Certificate Workflows

Both examined BIM to EPC workflows can be applied on buildings. However, the process is extremely laborious and error prone. This is caused by the time-consuming pre- and post-processing of the BIM model and the either manual or semi-automatic model transfer, whereby essential elements for the EP assessment are often not transferred to the EP Tool. Time-intensive processes imply high expenses, which can be enormously reduced by simply using a manual workflow without using BIM data. This can be done for example in *ArchiPHYSIK*, to obtain an EPC, which makes the semi-automatic BIM to EP Tools workflow redundant. Currently, the common time to calculate EPCs is shortly before the submission, when the architectural model already needs to have LoD300. In this thesis the reference BIM building is modelled in the rather high LoD300. In general, the Level of Detail of the models play an essential part in the data transfer. When first testing the suggested ArchiCAD to *ArchiPHYSIK* workflow the BIM model LoD300 needed to be pre-processed and reduced to a very low LoD. Therefore, to ensure the best results for the semi-automatic BIM to EPC workflow it is advisable to provide *ArchiCAD* models with a very low LoD for each zone. This is especially necessary when the building shows a rather complex geometry and consists of multiple zones. In contrast to this, *SIMULTAN* requires to remodel the whole geometrical as well as the data model manually. Thus, the level of detail of the BIM model for the *ArchiCAD* to *SIMULTAN* workflow is not relevant. Either way, it is questionable creating an architectural ArchiCAD BIM model with LoD300 and then reduce it to a low level for the final transfer. The data in *ArchiPHYSIK* obviously cannot be reused for any other use than the few simulations that are included in this EP Tool. Yet, the novel data platform *SIMULTAN* has potential for further simulations due to data transfer to Excel-Worksheets with the Excel-Tool editor. The user extracts all data needed for

simulations and calculations, without manipulating the data nor the geometrical model. However, this method is also significant time-intensive and requires an enormous high level of specialist knowledge.

As a suggestion, the architectural BIM software could be able to hold a feature for basic simulations just as the EPC that is based on the steady monthly balance method.

## 7.2. Energy Performance Simulation

For improving the energy performance of a building, it is advisable to transfer the data to an EP Tool and create a variant study at early design stage. Of course, the sooner the variants are provided the better the stakeholders can decide on the most suitable variant for a sustainable and energy-efficient building. Unfortunately, simple EPCs based on the steady monthly balance method are usually generated shortly before the submission. However, this method is imprecise, yet it is the standard in current design practice. By using dynamic simulations, the results would become more exact. Nevertheless, both simulations methods merely visualise the expected energy demand. The real energy consumption simulation can be reached only by considering user-specific influencing factors - the users behaviour. The dynamic simulations are especially interesting during operation of the building for detection of energy peaks, heat loss, summer overheating etc. However, for either method, a user-friendly interface is essential to motivate planners to simulate and examine different designs already at early design stage. Both examined workflows build a sufficient basis for the semi-creation of EPCs but still need improvement in ease of use and usefulness to serve as early decision-making tools to quickly carry out variant studies.

Additionally, especially *SIMULTAN* expects users to have subject specific knowledge as well as interdisciplinary expertise. Of course, it is important to have this expert qualification when preparing and calculating simulations. However, this implies that especially the architect needs to have also a specialist know-how in this field or must consult an expert. In German-speaking countries architects are more likely to have this specific building-physics expertise, according to the Austrian LM.VM 2014. (Lechner, 2014) Further, to reach an excellent building performance it is advisable to consult real specialists with the essential knowledge and innovative ideas. Beyond that, the architect has to declare and convince clients to consult building physicists and other specialists in the early design stage already to ensure outstanding EP results. This concept of the integrated design process (IDP) is necessary to fulfil the requirements of all stakeholders and find an appropriate solution for an excellent energy-efficiency combined with an outstanding design. During the IDP, the architect strives to find an optimal design in terms of functionality, building services, and design requirement, whereby the building

services should not obstruct. Of course, the IDP combined with an outstanding EP are more expensive during the planning phase. Yet, due to the energy savings this is profitable after 5 to 10 years. The expenses during the planning process can be reduced by defining a modelling standard and using compatible software. These measures are taken to save time during modelling as well as causing a minimum of data loss while transferring the model from one to another software.

### 7.3. Impact of different Facade Systems on the overall Energy Performance

The EPC results obtained by *ArchiPHYSIK* and *SIMULTAN* diverge quite a lot. The reasons for this already occurred during the data transfer to the EP tools, whereby the gross floor area and the volume showed different values in *ArchiPHYSIK* compared to *SIMULTAN*. The gross floor area as well as the volume are basic data for the calculations. Another reason are the utilisation profiles and the HVAC system. *ArchiPHYSIK* and *SIMULTAN* use different ways of data input for these profiles. Further, in contrary to *ArchiPHYSIK*, which is a software authorised by the Austrian regulative, *SIMULTAN* is currently being developed. The EPC obtained in *SIMULTAN* are calculated in the Excel-Tool TopPhiCO2 that is utilising another Excel-Tool the so-called Excel-Validierungs-Tool, whereby both are not published.

Considering all these issues, the more reliable EPC results are obtained by *ArchiPHYSIK*,

The EPC results generated with the customised facade system show the best results in all zones compared to the standard and high-end facade system. The worst EPC results are obtained by the high-end facade system, due to the high U-Values in the exterior walls and roofs. Although, considering the office area there is almost no distinction between standard and high-end facade system. The values of the industrial area are slightly better by using standard than the high-end facade system. Yet, due to the generous use of material the customised facade system is the most effective one.

### 7.4. Future Outlook

In general, BIM as a process, software, paradigm, as well as a model is gaining more importance in design practice and is expected to be the ruling modelling and planning type of the AEC industry. Nevertheless, more convenient solutions must be provided considering interoperability, interface communication, data loss, and ease of use, when multiple stakeholders and discipline-specific models are used. At the moment, the BIM to EPC process is still time consuming due to the necessary pre- and post-processing of the models. Improved workflows need to have a seamless data and model transfer from a BIM model to a BEM model that could counteract potential data loss during design, resulting in

improved energy performance of buildings. Another suggested solution would be the integration of EP simulations directly into the BIM-authoring-software. However, the concept of closed-BIM already offers satisfying solutions where a minimum data loss is possible (Autodesk, 2021). Yet, the open-BIM process will be prevalent with different BIM software, which still will be accompanied by interoperability, data loss, ease of use and time-intense process issues. By developing joint-project guidelines as well as modelling standards within the project teams at early design stage, the collaboration of various software and stakeholder can be improved.

Nevertheless, the software engineers are ought to develop more convenient BIM software solutions. The current industry standard transferring data between BIM software is via IFC. Neither *ArchiPHYSIK* nor *SIMULTAN* operate with IFC format yet. Therefore, it is uncertain if the transfer via IFC improves the process or will cause more problems. For exactly this reason *SIMULTAN*'s individual approach might be quite interesting, but as well uncertain if an IFC transfer is possible without any data loss.



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## Appendix

1. EPC A.C. – Energy Performance Certificate ArchiPHYSIK Customised Facade System
2. EPC S.C. – Energy Performance Certificate SIMULTAN Customised Facade System
3. EPC A.S. – Energy Performance Certificate ArchiPHYSIK Standard Facade System
4. EPC S.S. – Energy Performance Certificate SIMULTAN Standard Facade System
5. EPC A.H. – Energy Performance Certificate ArchiPHYSIK High-End Facade System
6. EPC S.H. – Energy Performance Certificate SIMULTAN High-End Facade System

# Energieausweis für Nicht-Wohngebäude



BEZEICHNUNG	TESTING_Workflow_EPCAC.		
Gebäude(-teil)	Office Area	Baujahr	2020
Nutzungsprofil	Bürogebäude	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nr.	81135
Grundstücksnr.		Seehöhe	594 m

## SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZFAKTOR

	HWB Ref,SK	PEB SK	CO2 SK	f GEE
<b>A ++</b>				
<b>A +</b>				
<b>A</b>				<b>A</b>
<b>B</b>	<b>B</b>			
<b>C</b>		<b>C</b>	<b>C</b>	
<b>D</b>				
<b>E</b>				
<b>F</b>				
<b>G</b>				

**HWB<sub>Ref</sub>:** 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.

**KB:** Der **Kühlbedarf** ist jene Wärmemenge, welche aus den Räumen abgeführt werden muss, um unter der Solltemperatur zu bleiben. Er errechnet sich aus den nicht nutzbaren inneren und solaren Gewinnen.

**BefEB:** Beim **Befeuchtungsenergiebedarf** wird der allfällige Energiebedarf zur Befeuchtung dargestellt.

**KEB:** Beim **Kühlenergiebedarf** werden zusätzlich zum Kühlbedarf die Verluste des Kühlsystems und der Kältebereitstellung berücksichtigt.

**BelEB:** Der **Beleuchtungsenergiebedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht dem Energiebedarf zur nutzungsgerechten Beleuchtung.

**BSB:** Der **Betriebsstrombedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht der Hälfte der mittleren innenren Lasten.

**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<sub>GEE</sub>:** 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<sub>em</sub>) und einen nicht erneuerbaren (PEB<sub>n.em</sub>) Anteil auf.

**CO<sub>2</sub>:** 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 des Energieausweis-Vorlage-Gesetzes (EAVG). Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.



# Energieausweis für Nicht-Wohngebäude

## GEBÄUDEKENNDATEN

Brutto-Grundfläche	2.426,93 m <sup>2</sup>	charakteristische Länge	3,02 m	mittlerer U-Wert	0,473 W/m <sup>2</sup> K
Bezugsfläche	1.941,54 m <sup>2</sup>	Klimaregion	NF	LEK <sub>T</sub> -Wert	28,27
Brutto-Volumen	9.407,20 m <sup>3</sup>	Heiztage	248 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	3.110,39 m <sup>2</sup>	Heizgradtage	3715 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	0,33 1/m	Norm-Außentemperatur	-12,0 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima) Office Area

Referenz-Heizwärmebedarf	<b>erfüllt</b>	41,18 kWh/m <sup>2</sup> a	≥ HWB <sub>Ref,RK</sub>	38,61 kWh/m <sup>2</sup> a
Außeninduzierter Kühlbedarf	<b>nicht erfüllt</b>	1,00 kWh/m <sup>2</sup> a	> KB* <sub>RK</sub>	10,49 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	<b>erfüllt (alternativ zu f<sub>GEE</sub>)</b>	117,57 kWh/m <sup>2</sup> a	≥ E/LEB <sub>RK</sub>	100,49 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	ohne Anforderungen		f <sub>GEE</sub>	0,765
Erneuerbarer Anteil	<b>erfüllt</b>			

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	109.724 kWh/a	HWB <sub>Ref,SK</sub>	45,21 kWh/m <sup>2</sup> a
Heizwärmebedarf	94.307 kWh/a	HWB <sub>SK</sub>	38,86 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	11.425 kWh/a	WWWB	4,71 kWh/m <sup>2</sup> a
Heizenergiebedarf	125.789 kWh/a	HEB <sub>SK</sub>	51,83 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		e <sub>AWZ,H</sub>	1,19
Kühlbedarf	210.329 kWh/a	KB <sub>SK</sub>	86,66 kWh/m <sup>2</sup> a
Kühlenergiebedarf	0 kWh/a	KEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Energieaufwandszahl Kühlen		e <sub>AWZ,K</sub>	0,00
Befeuchtungsenergiebedarf	0 kWh/a	BefEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Beleuchtungsenergiebedarf	78.147 kWh/a	BeLEB	32,20 kWh/m <sup>2</sup> a
Betriebsstrombedarf	59.793 kWh/a	BSB	24,64 kWh/m <sup>2</sup> a
Endenergiebedarf	263.730 kWh/a	EEB <sub>SK</sub>	108,67 kWh/m <sup>2</sup> a
Primärenergiebedarf	454.787 kWh/a	PEB <sub>SK</sub>	187,39 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	355.652 kWh/a	PEB <sub>n.ern.,SK</sub>	146,54 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	99.135 kWh/a	PEB <sub>ern.,SK</sub>	40,85 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	74.672 kg/a	CO <sub>2</sub> <sub>SK</sub>	30,77 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		f <sub>GEE</sub>	0,763
Photovoltaik-Export	0 kWh/a	PV <sub>Export,SK</sub>	0,00 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	13.10.2020	Unterschrift
Gültigkeitsdatum	12.10.2030	

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.

# Energieausweis für Nicht-Wohngebäude

**OiB** ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OiB-Richtlinie 6  
Ausgabe März 2015



BEZEICHNUNG	TESTING_Workflow_EPCAC.		
Gebäude(-teil)	Industrial Area	Baujahr	2020
Nutzungsprofil	Veranstaltungsstätten	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nr.	81135
Grundstücksnr.		Seehöhe	594 m

## SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZFAKTOR

	HWB Ref,SK	PEB sk	CO2 sk	f GEE
<b>A ++</b>				<b>A++</b>
<b>A +</b>				
<b>A</b>				
<b>B</b>				
<b>C</b>	<b>C</b>			
<b>D</b>		<b>E</b>	<b>D</b>	
<b>E</b>				
<b>F</b>				
<b>G</b>				

**HWB<sub>Ref</sub>**: 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.

**KB**: Der **Kühlbedarf** ist jene Wärmemenge, welche aus den Räumen abgeführt werden muss, um unter der Solltemperatur zu bleiben. Er errechnet sich aus den nicht nutzbaren inneren und solaren Gewinnen.

**BefEB**: Beim **Befeuchtungsenergiebedarf** wird der allfällige Energiebedarf zur Befeuchtung dargestellt.

**KEB**: Beim **Kühlenergiebedarf** werden zusätzlich zum Kühlbedarf die Verluste des Kühlsystems und der Kältebereitstellung berücksichtigt.

**BelEB**: Der **Beleuchtungsenergiebedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht dem Energiebedarf zur nutzungsgerechten Beleuchtung.

**BSB**: Der **Betriebsstrombedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht der Hälfte der mittleren innen Lasten.

**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).

**fGEE**: 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<sub>em</sub>) und einen nicht erneuerbaren (PEB<sub>n.em</sub>) Anteil auf.

**CO<sub>2</sub>**: 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 des Energieausweis-Vorlage-Gesetzes (EAVG). Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

Die approbierte gedruckte Originalversion dieser Diplomarbeit ist an der TU Wien Bibliothek verfügbar. The approved original version of this thesis is available in print at TU Wien Bibliothek.



# Energieausweis für Nicht-Wohngebäude

OiB ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OiB-Richtlinie 6  
Ausgabe März 2015



## GEBÄUDEKENNDATEN

Brutto-Grundfläche	19.953,14 m <sup>2</sup>	charakteristische Länge	5,59 m	mittlerer U-Wert	0,275 W/m <sup>2</sup> K
Bezugsfläche	15.962,51 m <sup>2</sup>	Klimaregion	NF	LEK <sub>T</sub> -Wert	10,87
Brutto-Volumen	257.609,60 m <sup>3</sup>	Heiztage	248 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	46.120,64 m <sup>2</sup>	Heizgradtage	3715 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	0,18 1/m	Norm-Außentemperatur	-12,0 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima) Industrial Area

Referenz-Heizwärmebedarf	<b>erfüllt</b>	105,84 kWh/m <sup>2</sup> a	≥ HWB <sub>Ref,RK</sub>	52,94 kWh/m <sup>2</sup> a
Außeninduzierter Kühlbedarf	<b>erfüllt</b>	1,00 kWh/m <sup>2</sup> a	≤ KB* <sub>RK</sub>	0,08 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	<b>erfüllt</b> (alternativ zu f <sub>GEE</sub> )	459,74 kWh/m <sup>2</sup> a	≥ E/LEB <sub>RK</sub>	152,89 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	ohne Anforderungen		f <sub>GEE</sub>	0,302
Erneuerbarer Anteil	<b>erfüllt</b>			

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	1.270.231 kWh/a	HWB <sub>Ref,SK</sub>	63,66 kWh/m <sup>2</sup> a
Heizwärmebedarf	1.242.604 kWh/a	HWB <sub>SK</sub>	62,28 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	254.901 kWh/a	WWWB	12,78 kWh/m <sup>2</sup> a
Heizenergiebedarf	1.804.810 kWh/a	HEB <sub>SK</sub>	90,45 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		e <sub>AWZ,H</sub>	1,20
Kühlbedarf	705.316 kWh/a	KB <sub>SK</sub>	35,35 kWh/m <sup>2</sup> a
Kühlenergiebedarf	0 kWh/a	KEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Energieaufwandszahl Kühlen		e <sub>AWZ,K</sub>	0,00
Befeuchtungsenergiebedarf	0 kWh/a	BefEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Beleuchtungsenergiebedarf	540.730 kWh/a	BelEB	27,10 kWh/m <sup>2</sup> a
Betriebsstrombedarf	983.191 kWh/a	BSB	49,28 kWh/m <sup>2</sup> a
Endenergiebedarf	3.328.731 kWh/a	EEB <sub>SK</sub>	166,83 kWh/m <sup>2</sup> a
Primärenergiebedarf	5.655.590 kWh/a	PEB <sub>SK</sub>	283,44 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	4.501.970 kWh/a	PEB <sub>n.ern.,SK</sub>	225,63 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	1.153.620 kWh/a	PEB <sub>ern.,SK</sub>	57,82 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	945.741 kg/a	CO <sub>2</sub> <sub>SK</sub>	47,40 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		f <sub>GEE</sub>	0,306
Photovoltaik-Export	0 kWh/a	PV <sub>Export,SK</sub>	0,00 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	13.10.2020	Unterschrift
Gültigkeitsdatum	12.10.2030	

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.

Die approbierte gedruckte Originalversion dieser Diplomarbeit ist an der TU Wien Bibliothek verfügbar. The approved original version of this thesis is available in print at TU Wien Bibliothek.

# Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6  
Ausgabe: März 2015

LOGO

**BEZEICHNUNG** TESTING\_Workflow\_EPC S.C.

Gebäude(-teil)	Office Aea	Baujahr	2021
Nutzungsprofil	Bürogebäude	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nummer:	81135
Grundstücksnummer		Seehöhe	594 m

## GEBÄUDEKENNDATEN

Brutto-Grundfläche	2 279,20 m <sup>2</sup>	charakteristische Länge	6,04 m	mittlerer U-Wert	0,80 W/m <sup>2</sup> K
Bezugsfläche	1 823,36 m <sup>2</sup>	Heiztage	286 d	LEKT-Wert	---
Brutto-Volumen	12 561,74 m <sup>3</sup>	Heizgradtage	4 055 Kd	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	1 823,36 m <sup>2</sup>	Klimaregion	NF	Bauweise	schwer
Kompaktheit (A/V)	0,17 1/m	Norm-Außentemperatur	-11,30 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima)

Referenz-Heizwärmebedarf	HWBRef,RK	67,7 kWh/m <sup>2</sup> a
Heizwärmebedarf	HWBRK	56,4 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	E/LEBRK	127,4 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	fGEE	0,74
Erneuerbarer Anteil		

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	188 293 kWh/a	HWBRef,SK	67,7 kWh/m <sup>2</sup> a
Heizwärmebedarf	157 329 kWh/a	HWBSK	69,0 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	14 558 kWh/a	WWWB	6,4 kWh/m <sup>2</sup> a
Heizenergiebedarf	190 583 kWh/a	HEBSK	83,6 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		eAWZ,H	0,94
Haushaltsstrombedarf	56 154 kWh/a	HHSB	24,6 kWh/m <sup>2</sup> a
Endenergiebedarf	320 127 kWh/a	EEBSK	140,5 kWh/m <sup>2</sup> a
Primärenergiebedarf	552 975 kWh/a	PEBSK	242,6 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	226 421 kWh/a	PEBn.ern.,SK	99,3 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	326 555 kWh/a	PEBern.,SK	143,3 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	45 919 kg/a	CO2SK	20,1 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		fGEE	0,76
Photovoltaik-Export	0 kWh/a	PVExport,SK	0,0 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ErstellerIn	Clara Gmeiner
Ausstellungsdatum	12.03.2021	Unterschrift	
Gültigkeitsdatum	---		

# Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6  
Ausgabe: März 2015

LOGO

## BEZEICHNUNG

TESTING\_Workflow\_EPC S.C.

Gebäude(-teil)	Industrial Area	Baujahr	2021
Nutzungsprofil	Veranstaltungsstätte	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nummer:	81135
Grundstücksnummer		Seehöhe	594 m

## GEBÄUDEKENNDATEN

Brutto-Grundfläche	27 705,28 m <sup>2</sup>	charakteristische Länge	167,82 m	mittlerer U-Wert	4,47 W/m <sup>2</sup> K
Bezugsfläche	22 164,23 m <sup>2</sup>	Heiztage	196 d	LEKT-Wert	---
Brutto-Volumen	349 065,71 m <sup>3</sup>	Heizgradtage	4 055 Kd	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	22 164,23 m <sup>2</sup>	Klimaregion	NF	Bauweise	schwer
Kompaktheit (AV)	0,01 1/m	Norm-Außentemperatur	-11,30 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima)

Referenz-Heizwärmebedarf	HWBRef,RK	43,6 kWh/m <sup>2</sup> a
Heizwärmebedarf	HWBRK	18,1 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	E/LEBRK	116,2 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	fGEE	0,27
Erneuerbarer Anteil		

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	1 206 925 kWh/a	HWBRef,SK	43,6 kWh/m <sup>2</sup> a
Heizwärmebedarf	652 514 kWh/a	HWBSK	23,6 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	353 935 kWh/a	WWWB	12,8 kWh/m <sup>2</sup> a
Heizenergiebedarf	1 253 109 kWh/a	HEBSK	45,2 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		eAWZ,H	0,80
Haushaltsstrombedarf	1 365 178 kWh/a	HHSB	49,3 kWh/m <sup>2</sup> a
Endenergiebedarf	3 369 100 kWh/a	EEBSK	121,6 kWh/m <sup>2</sup> a
Primärenergiebedarf	6 072 961 kWh/a	PEBSK	219,2 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	3 232 692 kWh/a	PEBn.ern.,SK	116,7 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	2 840 269 kWh/a	PEBern.,SK	102,5 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	667 115 kg/a	CO2SK	24,1 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		fGEE	0,27
Photovoltaik-Export	0 kWh/a	PVExport,SK	0,0 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ErstellerIn	Clara Gmeiner
Ausstellungsdatum	12.03.2021	Unterschrift	
Gültigkeitsdatum	---		

# Energieausweis für Nicht-Wohngebäude

**OiB** ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OiB-Richtlinie 6  
Ausgabe März 2015



BEZEICHNUNG	IMPROVEMENT_Workflow_EPC.A.S.		
Gebäude(-teil)	Büro	Baujahr	2020
Nutzungsprofil	Bürogebäude	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nr.	81135
Grundstücksnr.		Seehöhe	594 m

## SPEZIFISCHER STANDORT-REFERENZ-HEIZWÄRMEBEDARF, STANDORT-PRIMÄRENERGIEBEDARF, STANDORT-KOHLENDIOXIDEMISSIONEN UND GESAMTENERGIEEFFIZIENZFAKTOR

	HWB Ref,SK	PEB sk	CO2 sk	f GEE
<b>A ++</b>				
<b>A +</b>				
<b>A</b>				<b>A</b>
<b>B</b>				
<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	
<b>D</b>				
<b>E</b>				
<b>F</b>				
<b>G</b>				

**HWB<sub>Ref</sub>**: 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.

**KB**: Der **Kühlbedarf** ist jene Wärmemenge, welche aus den Räumen abgeführt werden muss, um unter der Solltemperatur zu bleiben. Er errechnet sich aus den nicht nutzbaren inneren und solaren Gewinnen.

**BefEB**: Beim **Befeuchtungsenergiebedarf** wird der allfällige Energiebedarf zur Befeuchtung dargestellt.

**KEB**: Beim **Kühlenergiebedarf** werden zusätzlich zum Kühlbedarf die Verluste des Kühlsystems und der Kältebereitstellung berücksichtigt.

**BelEB**: Der **Beleuchtungsenergiebedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht dem Energiebedarf zur nutzungsgerechten Beleuchtung.

**BSB**: Der **Betriebsstrombedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht der Hälfte der mittleren innenren Lasten.

**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).

**fGEE**: 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<sub>em</sub>) und einen nicht erneuerbaren (PEB<sub>n.em</sub>) Anteil auf.

**CO<sub>2</sub>**: 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 des Energieausweis-Vorlage-Gesetzes (EAVG). Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

Die approbierte gedruckte Originalversion dieser Diplomarbeit ist an der TU Wien Bibliothek verfügbar  
The approved original version of this thesis is available in print at TU Wien Bibliothek.



# Energieausweis für Nicht-Wohngebäude

## GEBÄUDEKENNDATEN

Brutto-Grundfläche	2.431,92 m <sup>2</sup>	charakteristische Länge	3,28 m	mittlerer U-Wert	0,517 W/m <sup>2</sup> K
Bezugsfläche	1.945,53 m <sup>2</sup>	Klimaregion	NF	LEK <sub>T</sub> -Wert	29,36
Brutto-Volumen	10.392,66 m <sup>3</sup>	Heiztage	248 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	3.170,62 m <sup>2</sup>	Heizgradtage	3715 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	0,31 1/m	Norm-Außentemperatur	-12,0 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima) Büro

Referenz-Heizwärmebedarf	<b>nicht erfüllt</b>	43,65 kWh/m <sup>2</sup> a	<	HWB <sub>Ref,RK</sub>	43,84 kWh/m <sup>2</sup> a
Außeninduzierter Kühlbedarf	<b>nicht erfüllt</b>	1,00 kWh/m <sup>2</sup> a	>	KB* <sub>RK</sub>	8,79 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	<b>erfüllt</b> (alternativ zu f <sub>GEE</sub> )	127,35 kWh/m <sup>2</sup> a	≥	E/LEB <sub>RK</sub>	105,81 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	ohne Anforderungen			f <sub>GEE</sub>	0,741
Erneuerbarer Anteil	<b>erfüllt</b>				

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	124.643 kWh/a	HWB <sub>Ref,SK</sub>	51,25 kWh/m <sup>2</sup> a
Heizwärmebedarf	108.637 kWh/a	HWB <sub>SK</sub>	44,67 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	11.448 kWh/a	WWWB	4,71 kWh/m <sup>2</sup> a
Heizenergiebedarf	140.771 kWh/a	HEB <sub>SK</sub>	57,88 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		e <sub>AWZ,H</sub>	1,17
Kühlbedarf	195.870 kWh/a	KB <sub>SK</sub>	80,54 kWh/m <sup>2</sup> a
Kühlenergiebedarf	0 kWh/a	KEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Energieaufwandszahl Kühlen		e <sub>AWZ,K</sub>	0,00
Befeuchtungsenergiebedarf	0 kWh/a	BefEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Beleuchtungsenergiebedarf	78.308 kWh/a	BeIEB	32,20 kWh/m <sup>2</sup> a
Betriebsstrombedarf	59.916 kWh/a	BSB	24,64 kWh/m <sup>2</sup> a
Endenergiebedarf	278.995 kWh/a	EEB <sub>SK</sub>	114,72 kWh/m <sup>2</sup> a
Primärenergiebedarf	478.107 kWh/a	PEB <sub>SK</sub>	196,60 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	376.700 kWh/a	PEB <sub>n.ern.,SK</sub>	154,90 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	101.407 kWh/a	PEB <sub>ern.,SK</sub>	41,70 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	79.109 kg/a	CO <sub>2</sub> <sub>SK</sub>	32,53 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		f <sub>GEE</sub>	0,744
Photovoltaik-Export	0 kWh/a	PV <sub>Export,SK</sub>	0,00 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	13.10.2020	Unterschrift
Gültigkeitsdatum	12.10.2030	

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.

# Energieausweis für Nicht-Wohngebäude

**OiB** ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OiB-Richtlinie 6  
Ausgabe März 2015



BEZEICHNUNG	IMPROVEMENT_Workflow_EPC.A.S.		
Gebäude(-teil)	Industrie	Baujahr	2020
Nutzungsprofil	Veranstaltungsstätten	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nr.	81135
Grundstücksnr.		Seehöhe	594 m

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

	HWB Ref,SK	PEB sk	CO2 sk	f GEE
<b>A ++</b>				<b>A++</b>
<b>A +</b>				
<b>A</b>				
<b>B</b>				
<b>C</b>	<b>C</b>			
<b>D</b>		<b>E</b>	<b>D</b>	
<b>E</b>				
<b>F</b>				
<b>G</b>				

**HWB<sub>Ref</sub>**: 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.

**KB**: Der **Kühlbedarf** ist jene Wärmemenge, welche aus den Räumen abgeführt werden muss, um unter der Solltemperatur zu bleiben. Er errechnet sich aus den nicht nutzbaren inneren und solaren Gewinnen.

**BefEB**: Beim **Befeuchtungsenergiebedarf** wird der allfällige Energiebedarf zur Befeuchtung dargestellt.

**KEB**: Beim **Kühlenergiebedarf** werden zusätzlich zum Kühlbedarf die Verluste des Kühlsystems und der Kältebereitstellung berücksichtigt.

**BelEB**: Der **Beleuchtungsenergiebedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht dem Energiebedarf zur nutzungsgerechten Beleuchtung.

**BSB**: Der **Betriebsstrombedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht der Hälfte der mittleren innenren Lasten.

**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).

**fGEE**: 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<sub>em</sub>) und einen nicht erneuerbaren (PEB<sub>n.em</sub>) Anteil auf.

**CO<sub>2</sub>**: 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 des Energieausweis-Vorlage-Gesetzes (EAVG). Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

Die approbierte gedruckte Originalversion dieser Diplomarbeit ist an der TU Wien Bibliothek verfügbar  
The approved original version of this thesis is available in print at TU Wien Bibliothek.





# Energieausweis für Nicht-Wohngebäude

## GEBÄUDEKENNDATEN

Brutto-Grundfläche	20.473,73 m <sup>2</sup>	charakteristische Länge	5,99 m	mittlerer U-Wert	0,319 W/m <sup>2</sup> K
Bezugsfläche	16.378,98 m <sup>2</sup>	Klimaregion	NF	LEK <sub>T</sub> -Wert	11,97
Brutto-Volumen	275.936,42 m <sup>3</sup>	Heiztage	248 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	46.085,41 m <sup>2</sup>	Heizgradtage	3715 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	0,17 1/m	Norm-Außentemperatur	-12,0 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima) Industrie

Referenz-Heizwärmebedarf	<b>erfüllt</b>	107,90 kWh/m <sup>2</sup> a	≥ HWB <sub>Ref,RK</sub>	59,72 kWh/m <sup>2</sup> a
Außeninduzierter Kühlbedarf	<b>erfüllt</b>	1,00 kWh/m <sup>3</sup> a	≤ KB* <sub>RK</sub>	0,00 kWh/m <sup>3</sup> a
End-/Lieferenergiebedarf	<b>erfüllt (alternativ zu f<sub>GEE</sub>)</b>	475,98 kWh/m <sup>2</sup> a	≥ E/LEB <sub>RK</sub>	160,21 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	ohne Anforderungen		f <sub>GEE</sub>	0,305
Erneuerbarer Anteil	<b>erfüllt</b>			

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	1.477.466 kWh/a	HWB <sub>Ref,SK</sub>	72,16 kWh/m <sup>2</sup> a
Heizwärmebedarf	1.441.692 kWh/a	HWB <sub>SK</sub>	70,42 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	261.552 kWh/a	WWWB	12,78 kWh/m <sup>2</sup> a
Heizenergiebedarf	2.022.869 kWh/a	HEB <sub>SK</sub>	98,80 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		e <sub>AWZ,H</sub>	1,18
Kühlbedarf	576.054 kWh/a	KB <sub>SK</sub>	28,14 kWh/m <sup>2</sup> a
Kühlenergiebedarf	0 kWh/a	KEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Energieaufwandszahl Kühlen		e <sub>AWZ,K</sub>	0,00
Befeuchtungsenergiebedarf	0 kWh/a	BefEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Beleuchtungsenergiebedarf	554.838 kWh/a	BeIEB	27,10 kWh/m <sup>2</sup> a
Betriebsstrombedarf	1.008.843 kWh/a	BSB	49,28 kWh/m <sup>2</sup> a
Endenergiebedarf	3.586.550 kWh/a	EEB <sub>SK</sub>	175,18 kWh/m <sup>2</sup> a
Primärenergiebedarf	6.063.075 kWh/a	PEB <sub>SK</sub>	296,14 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	4.855.360 kWh/a	PEB <sub>n.ern.,SK</sub>	237,15 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	1.207.715 kWh/a	PEB <sub>ern.,SK</sub>	58,99 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	1.020.166 kg/a	CO <sub>2</sub> <sub>SK</sub>	49,83 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		f <sub>GEE</sub>	0,311
Photovoltaik-Export	0 kWh/a	PV <sub>Export,SK</sub>	0,00 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	13.10.2020	Unterschrift
Gültigkeitsdatum	12.10.2030	

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.

# Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6  
Ausgabe: März 2015

LOGO

## BEZEICHNUNG

IMPROVEMENT\_Workflow\_EPC S.S.

Gebäude(-teil)	Office Area	Baujahr	
Nutzungsprofil	Bürogebäude	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nummer:	81135
Grundstücksnummer		Seehöhe	594 m

## GEBÄUDEKENNDATEN

Brutto-Grundfläche	2 168,33 m <sup>2</sup>	charakteristische Länge	5,85 m	mittlerer U-Wert	0,87 W/m <sup>2</sup> K
Bezugsfläche	1 734,67 m <sup>2</sup>	Heiztage	298 d	LEKT-Wert	---
Brutto-Volumen	12 159,09 m <sup>3</sup>	Heizgradtage	4 055 Kd	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	1 734,67 m <sup>2</sup>	Klimaregion	NF	Bauweise	schwer
Kompaktheit (AV)	0,17 1/m	Norm-Außentemperatur	-11,30 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima)

Referenz-Heizwärmebedarf	HWBRef,RK	77,3 kWh/m <sup>2</sup> a
Heizwärmebedarf	HWBRK	65,5 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	E/LEBRK	136,6 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	fGEE	0,78
Erneuerbarer Anteil		

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	204 736 kWh/a	HWBRef,SK	94,4 kWh/m <sup>2</sup> a
Heizwärmebedarf	174 006 kWh/a	HWBSK	80,2 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	13 850 kWh/a	WWWB	6,4 kWh/m <sup>2</sup> a
Heizenergiebedarf	205 957 kWh/a	HEBSK	95,0 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		eAWZ,H	0,94
Haushaltsstrombedarf	53 422 kWh/a	HHSB	24,6 kWh/m <sup>2</sup> a
Endenergiebedarf	329 199 kWh/a	EEBSK	151,8 kWh/m <sup>2</sup> a
Primärenergiebedarf	565 528 kWh/a	PEBSK	260,8 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	222 374 kWh/a	PEBn.ern.,SK	102,6 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	343 154 kWh/a	PEBem.,SK	158,3 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	44 957 kg/a	CO2SK	20,7 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		fGEE	0,81
Photovoltaik-Export	0 kWh/a	PVExport,SK	0,0 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ErstellerIn	Clara Gmeiner
Ausstellungsdatum	12.03.2021	Unterschrift	
Gültigkeitsdatum	---		

# Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6  
Ausgabe: März 2015

LOGO

**BEZEICHNUNG** IMPROVEMENT\_Workflow\_EPC S.S.

Gebäude(-teil)	Industrial Area	Baujahr	2021
Nutzungsprofil	Veranstaltungsstätte	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nummer:	81135
Grundstücksnummer		Seehöhe	594 m

## GEBÄUDEKENNDATEN

Brutto-Grundfläche	43 470,27 m <sup>2</sup>	charakteristische Länge	170,72 m	mittlerer U-Wert	8,01 W/m <sup>2</sup> K
Bezugsfläche	34 776,21 m <sup>2</sup>	Heiztage	206 d	LEKT-Wert	---
Brutto-Volumen	355 104,90 m <sup>3</sup>	Heizgradtage	4 055 Kd	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	34 776,21 m <sup>2</sup>	Klimaregion	NF	Bauweise	schwer
Kompaktheit (A/V)	0,01 1/m	Norm-Außentemperatur	-11,30 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima)

Referenz-Heizwärmebedarf	HWBRef,RK	39,6 kWh/m <sup>2</sup> a
Heizwärmebedarf	HWBRK	21,5 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	E/LEBRK	120,9 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	fGEE	0,43
Erneuerbarer Anteil		

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	2 120 035 kWh/a	HWBRef,SK	48,8 kWh/m <sup>2</sup> a
Heizwärmebedarf	1 219 483 kWh/a	HWBSK	28,1 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	555 333 kWh/a	WWWB	12,8 kWh/m <sup>2</sup> a
Heizenergiebedarf	2 208 161 kWh/a	HEBSK	50,8 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		eAWZ,H	0,83
Haushaltsstrombedarf	2 141 997 kWh/a	HHSB	49,3 kWh/m <sup>2</sup> a
Endenergiebedarf	5 528 203 kWh/a	EEBSK	127,2 kWh/m <sup>2</sup> a
Primärenergiebedarf	9 932 217 kWh/a	PEBSK	228,5 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	5 194 918 kWh/a	PEBn.ern.,SK	119,5 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	4 737 299 kWh/a	PEBern.,SK	109,0 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	1 070 957 kg/a	CO2SK	24,6 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		fGEE	0,44
Photovoltaik-Export	0 kWh/a	PVExport,SK	0,0 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ErstellerIn	Clara Gmeiner
Ausstellungsdatum	12.03.2021	Unterschrift	
Gültigkeitsdatum	---		

# Energieausweis für Nicht-Wohngebäude

**OiB** ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OiB-Richtlinie 6  
Ausgabe März 2015



BEZEICHNUNG	REPLACEMENT_Workflow_EPCA.H		
Gebäude(-teil)	Office Area	Baujahr	2020
Nutzungsprofil	Bürogebäude	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nr.	81135
Grundstücksnr.		Seehöhe	594 m

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

	HWB Ref,SK	PEB sk	CO2 sk	f GEE
<b>A ++</b>				
<b>A +</b>				
<b>A</b>				<b>A</b>
<b>B</b>				
<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	
<b>D</b>				
<b>E</b>				
<b>F</b>				
<b>G</b>				

**HWB<sub>Ref</sub>:** 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.

**KB:** Der **Kühlbedarf** ist jene Wärmemenge, welche aus den Räumen abgeführt werden muss, um unter der Solltemperatur zu bleiben. Er errechnet sich aus den nicht nutzbaren inneren und solaren Gewinnen.

**BefEB:** Beim **Befeuchtungsennergiebedarf** wird der allfällige Energiebedarf zur Befeuchtung dargestellt.

**KEB:** Beim **Kühlenergiebedarf** werden zusätzlich zum Kühlbedarf die Verluste des Kühlsystems und der Kältebereitstellung berücksichtigt.

**BelEB:** Der **Beleuchtungsennergiebedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht dem Energiebedarf zur nutzungsgerechten Beleuchtung.

**BSB:** Der **Betriebsstrombedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht der Hälfte der mittleren inneren Lasten.

**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<sub>GEE</sub>:** 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<sub>em</sub>) und einen nicht erneuerbaren (PEB<sub>n.em</sub>) Anteil auf.

**CO<sub>2</sub>:** 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 des Energieausweis-Vorlage-Gesetzes (EAVG). Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

Die approbierte gedruckte Originalversion dieser Diplomarbeit ist an der TU Wien Bibliothek verfügbar  
The approved original version of this thesis is available in print at TU Wien Bibliothek.



# Energieausweis für Nicht-Wohngebäude

## GEBÄUDEKENNDATEN

Brutto-Grundfläche	2.431,92 m <sup>2</sup>	charakteristische Länge	3,28 m	mittlerer U-Wert	0,511 W/m <sup>2</sup> K
Bezugsfläche	1.945,53 m <sup>2</sup>	Klimaregion	NF	LEK <sub>T</sub> -Wert	29,02
Brutto-Volumen	10.392,66 m <sup>3</sup>	Heiztage	248 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	3.170,62 m <sup>2</sup>	Heizgradtage	3715 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	0,31 1/m	Norm-Außentemperatur	-12,0 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima) Office Area

Referenz-Heizwärmebedarf	<b>erfüllt</b>	43,65 kWh/m <sup>2</sup> a	≥ HWB <sub>Ref,RK</sub>	43,21 kWh/m <sup>2</sup> a
Außeninduzierter Kühlbedarf	<b>nicht erfüllt</b>	1,00 kWh/m <sup>2</sup> a	> KB* <sub>RK</sub>	8,79 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	ohne Anforderungen		E/LEB <sub>RK</sub>	105,23 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	<b>erfüllt</b> (alternativ zu EEB <sub>max,RK</sub> )	0,900	≥ f <sub>GEE</sub>	0,737
Erneuerbarer Anteil	<b>erfüllt</b>			

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	122.885 kWh/a	HWB <sub>Ref,SK</sub>	50,53 kWh/m <sup>2</sup> a
Heizwärmebedarf	106.906 kWh/a	HWB <sub>SK</sub>	43,96 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	11.448 kWh/a	WWWB	4,71 kWh/m <sup>2</sup> a
Heizenergiebedarf	138.910 kWh/a	HEB <sub>SK</sub>	57,12 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		e <sub>AWZ,H</sub>	1,17
Kühlbedarf	197.514 kWh/a	KB <sub>SK</sub>	81,22 kWh/m <sup>2</sup> a
Kühlenergiebedarf	0 kWh/a	KEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Energieaufwandszahl Kühlen		e <sub>AWZ,K</sub>	0,00
Befeuchtungsenergiebedarf	0 kWh/a	BefEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Beleuchtungsenergiebedarf	78.308 kWh/a	BelEB	32,20 kWh/m <sup>2</sup> a
Betriebsstrombedarf	59.916 kWh/a	BSB	24,64 kWh/m <sup>2</sup> a
Endenergiebedarf	277.134 kWh/a	EEB <sub>SK</sub>	113,96 kWh/m <sup>2</sup> a
Primärenergiebedarf	475.273 kWh/a	PEB <sub>SK</sub>	195,43 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	374.133 kWh/a	PEB <sub>n.ern.,SK</sub>	153,84 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	101.140 kWh/a	PEB <sub>ern.,SK</sub>	41,59 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	78.568 kg/a	CO <sub>2</sub> <sub>SK</sub>	32,31 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		f <sub>GEE</sub>	0,739
Photovoltaik-Export	0 kWh/a	PV <sub>Export,SK</sub>	0,00 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	13.10.2020	Unterschrift
Gültigkeitsdatum	12.10.2030	

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.

# Energieausweis für Nicht-Wohngebäude



OiB ÖSTERREICHISCHES INSTITUT FÜR BAUTECHNIK

OiB-Richtlinie 6  
Ausgabe März 2015

BEZEICHNUNG	REPLACEMENT_Workflow_EPCA.H.		
Gebäude(-teil)	Industrial Area	Baujahr	2020
Nutzungsprofil	Veranstaltungsstätten	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nr.	81135
Grundstücksnr.		Seehöhe	594 m

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

	HWB Ref,SK	PEB sk	CO2 sk	f GEE
A ++				A ++
A +				
A				
B				
C	C			
D				
E		E	E	
F				
G				

**HWB<sub>Ref</sub>:** 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.

**KB:** Der **Kühlbedarf** ist jene Wärmemenge, welche aus den Räumen abgeführt werden muss, um unter der Solltemperatur zu bleiben. Er errechnet sich aus den nicht nutzbaren inneren und solaren Gewinnen.

**BefEB:** Beim **Befeuchtungsenergiebedarf** wird der allfällige Energiebedarf zur Befeuchtung dargestellt.

**KEB:** Beim **Kühlenergiebedarf** werden zusätzlich zum Kühlbedarf die Verluste des Kühlsystems und der Kältebereitstellung berücksichtigt.

**BelEB:** Der **Beleuchtungsenergiebedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht dem Energiebedarf zur nutzungsgerechten Beleuchtung.

**BSB:** Der **Betriebsstrombedarf** ist als flächenbezogener Defaultwert festgelegt und entspricht der Hälfte der mittleren inneren Lasten.

**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<sub>GEE</sub>:** 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<sub>em</sub>) und einen nicht erneuerbaren (PEB<sub>n.em</sub>) Anteil auf.

**CO<sub>2</sub>:** 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 des Energieausweis-Vorlage-Gesetzes (EAVG). Der Ermittlungszeitraum für die Konversionsfaktoren für Primärenergie und Kohlendioxidemissionen ist 2004 - 2008 (Strom: 2009 - 2013), und es wurden übliche Allokationsregeln unterstellt.

Die approbierte gedruckte Originalversion dieser Diplomarbeit ist an der TU Wien Bibliothek verfügbar. The approved original version of this thesis is available in print at TU Wien Bibliothek.



# Energieausweis für Nicht-Wohngebäude

**OiB** ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OiB-Richtlinie 6  
Ausgabe März 2015



## GEBÄUDEKENNDATEN

Brutto-Grundfläche	20.473,73 m <sup>2</sup>	charakteristische Länge	5,99 m	mittlerer U-Wert	0,331 W/m <sup>2</sup> K
Bezugsfläche	16.378,98 m <sup>2</sup>	Klimaregion	NF	LEK <sub>T</sub> -Wert	12,44
Brutto-Volumen	275.936,42 m <sup>3</sup>	Heiztage	248 d	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	46.085,41 m <sup>2</sup>	Heizgradtage	3715 Kd	Bauweise	mittelschwere
Kompaktheit (A/V)	0,17 1/m	Norm-Außentemperatur	-12,0 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima) Industrial Area

Referenz-Heizwärmebedarf	<b>erfüllt</b>	107,90 kWh/m <sup>2</sup> a	≥ HWB <sub>Ref,RK</sub>	62,15 kWh/m <sup>2</sup> a
Außeninduzierter Kühlbedarf	<b>erfüllt</b>	1,00 kWh/m <sup>2</sup> a	≤ KB* <sub>RK</sub>	0,00 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	<b>erfüllt</b> (alternativ zu f <sub>GEE</sub> )	475,98 kWh/m <sup>2</sup> a	≥ E/LEB <sub>RK</sub>	162,97 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	ohne Anforderungen		f <sub>GEE</sub>	0,311
Erneuerbarer Anteil	<b>erfüllt</b>			

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	1.538.859 kWh/a	HWB <sub>Ref,SK</sub>	75,16 kWh/m <sup>2</sup> a
Heizwärmebedarf	1.501.462 kWh/a	HWB <sub>SK</sub>	73,34 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	261.552 kWh/a	WWWB	12,78 kWh/m <sup>2</sup> a
Heizenergiebedarf	2.093.173 kWh/a	HEB <sub>SK</sub>	102,24 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		e <sub>AWZ,H</sub>	1,18
Kühlbedarf	551.645 kWh/a	KB <sub>SK</sub>	26,94 kWh/m <sup>2</sup> a
Kühlenergiebedarf	0 kWh/a	KEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Energieaufwandszahl Kühlen		e <sub>AWZ,K</sub>	0,00
Befeuchtungsenergiebedarf	0 kWh/a	BefEB <sub>SK</sub>	0,00 kWh/m <sup>2</sup> a
Beleuchtungsenergiebedarf	554.838 kWh/a	BelEB	27,10 kWh/m <sup>2</sup> a
Betriebsstrombedarf	1.008.843 kWh/a	BSB	49,28 kWh/m <sup>2</sup> a
Endenergiebedarf	3.656.854 kWh/a	EEB <sub>SK</sub>	178,61 kWh/m <sup>2</sup> a
Primärenergiebedarf	6.169.961 kWh/a	PEB <sub>SK</sub>	301,36 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	4.952.375 kWh/a	PEB <sub>n.ern.,SK</sub>	241,89 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	1.217.586 kWh/a	PEB <sub>ern.,SK</sub>	59,47 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	1.040.624 kg/a	CO <sub>2</sub> <sub>SK</sub>	50,83 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		f <sub>GEE</sub>	0,317
Photovoltaik-Export	0 kWh/a	PV <sub>Export,SK</sub>	0,00 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ArchiPHYSIK - A-NULL - SCHULVERSION
Ausstellungsdatum	13.10.2020	Unterschrift
Gültigkeitsdatum	12.10.2030	

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.

# Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6  
Ausgabe: März 2015

LOGO

**BEZEICHNUNG** REPLACEMENT\_Workflow\_EPC S.H.

Gebäude(-teil)	Office Area	Baujahr	2021
Nutzungsprofil	Bürogebäude	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nummer:	81135
Grundstücksnummer		Seehöhe	594 m

## GEBÄUDEKENNDATEN

Brutto-Grundfläche	1 512,29 m <sup>2</sup>	charakteristische Länge	5,63 m	mittlerer U-Wert	0,74 W/m <sup>2</sup> K
Bezugsfläche	1 209,84 m <sup>2</sup>	Heiztage	307 d	LEKT-Wert	---
Brutto-Volumen	11 710,01 m <sup>3</sup>	Heizgradtage	4 055 Kd	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	1 209,84 m <sup>2</sup>	Klimaregion	NF	Bauweise	schwer
Kompaktheit (A/V)	0,18 1/m	Norm-Außentemperatur	-11,30 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima)

Referenz-Heizwärmebedarf	HWBRef,RK	91,6 kWh/m <sup>2</sup> a
Heizwärmebedarf	HWBRK	79,4 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	E/LEBRK	150,8 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	fGEE	0,62
Erneuerbarer Anteil		

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	168 934 kWh/a	HWBRef,SK	111,7 kWh/m <sup>2</sup> a
Heizwärmebedarf	146 748 kWh/a	HWBSK	97,0 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	9 660 kWh/a	WWWB	6,4 kWh/m <sup>2</sup> a
Heizenergiebedarf	169 653 kWh/a	HEBSK	112,2 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		eAWZ,H	0,95
Haushaltsstrombedarf	37 259 kWh/a	HHSB	24,6 kWh/m <sup>2</sup> a
Endenergiebedarf	255 608 kWh/a	EEBSK	169,0 kWh/m <sup>2</sup> a
Primärenergiebedarf	436 058 kWh/a	PEBSK	288,3 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	162 434 kWh/a	PEBn.ern.,SK	107,4 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	273 624 kWh/a	PEBem.,SK	180,9 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	32 694 kg/a	CO2SK	21,6 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		fGEE	0,65
Photovoltaik-Export	0 kWh/a	PVExport,SK	0,0 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ErstellerIn	Clara Gmeiner
Ausstellungsdatum	12.03.2021	Unterschrift	
Gültigkeitsdatum	---		



# Energieausweis für Wohngebäude

OIB ÖSTERREICHISCHES  
INSTITUT FÜR BAUTECHNIK

OIB-Richtlinie 6  
Ausgabe: März 2015

# LOGO

## BEZEICHNUNG

REPLACEMENT\_Workflow\_EPC S.H.

Gebäude(-teil)	Industrial Area	Baujahr	2021
Nutzungsprofil	Veranstaltungsstätte	Letzte Veränderung	
Straße	Florianiweg 16a	Katastralgemeinde	Völs
PLZ/Ort	6176 Völs	KG-Nummer:	81135
Grundstücksnummer		Seehöhe	594 m

## GEBÄUDEKENNDATEN

Brutto-Grundfläche	43 470,27 m <sup>2</sup>	charakteristische Länge	166,87 m	mittlerer U-Wert	7,65 W/m <sup>2</sup> K
Bezugsfläche	34 776,21 m <sup>2</sup>	Heiztage	203 d	LEKT-Wert	---
Brutto-Volumen	347 086,54 m <sup>3</sup>	Heizgradtage	4 055 Kd	Art der Lüftung	Fensterlüftung
Gebäude-Hüllfläche	34 776,21 m <sup>2</sup>	Klimaregion	NF	Bauweise	schwer
Kompaktheit (AV)	0,01 1/m	Norm-Außentemperatur	-11,30 °C	Soll-Innentemperatur	20 °C

## ANFORDERUNGEN (Referenzklima)

Referenz-Heizwärmebedarf	HWBRef,RK	38,1 kWh/m <sup>2</sup> a
Heizwärmebedarf	HWBRK	20,3 kWh/m <sup>2</sup> a
End-/Lieferenergiebedarf	E/LEBRK	119,7 kWh/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor	fGEE	0,44
Erneuerbarer Anteil		

## WÄRME- UND ENERGIEBEDARF (Standortklima)

Referenz-Heizwärmebedarf	2 040 156 kWh/a	HWBRef,SK	46,9 kWh/m <sup>2</sup> a
Heizwärmebedarf	1 151 691 kWh/a	HWBSK	26,5 kWh/m <sup>2</sup> a
Warmwasserwärmebedarf	555 333 kWh/a	WWWB	12,8 kWh/m <sup>2</sup> a
Heizenergiebedarf	2 141 821 kWh/a	HEBSK	49,3 kWh/m <sup>2</sup> a
Energieaufwandszahl Heizen		eAWZ,H	0,83
Haushaltsstrombedarf	2 141 997 kWh/a	HHSB	49,3 kWh/m <sup>2</sup> a
Endenergiebedarf	5 461 863 kWh/a	EEBSK	125,6 kWh/m <sup>2</sup> a
Primärenergiebedarf	9 826 074 kWh/a	PEBSK	226,0 kWh/m <sup>2</sup> a
Primärenergiebedarf nicht erneuerbar	5 176 343 kWh/a	PEBn.ern.,SK	119,1 kWh/m <sup>2</sup> a
Primärenergiebedarf erneuerbar	4 649 731 kWh/a	PEBern.,SK	107,0 kWh/m <sup>2</sup> a
Kohlendioxidemissionen (optional)	1 067 574 kg/a	CO2SK	24,6 kg/m <sup>2</sup> a
Gesamtenergieeffizienz-Faktor		fGEE	0,44
Photovoltaik-Export	0 kWh/a	PVExport,SK	0,0 kWh/m <sup>2</sup> a

## ERSTELLT

GWR-Zahl		ErstellerIn	Clara Gmeiner
Ausstellungsdatum	12.03.2021	Unterschrift	
Gültigkeitsdatum	---		