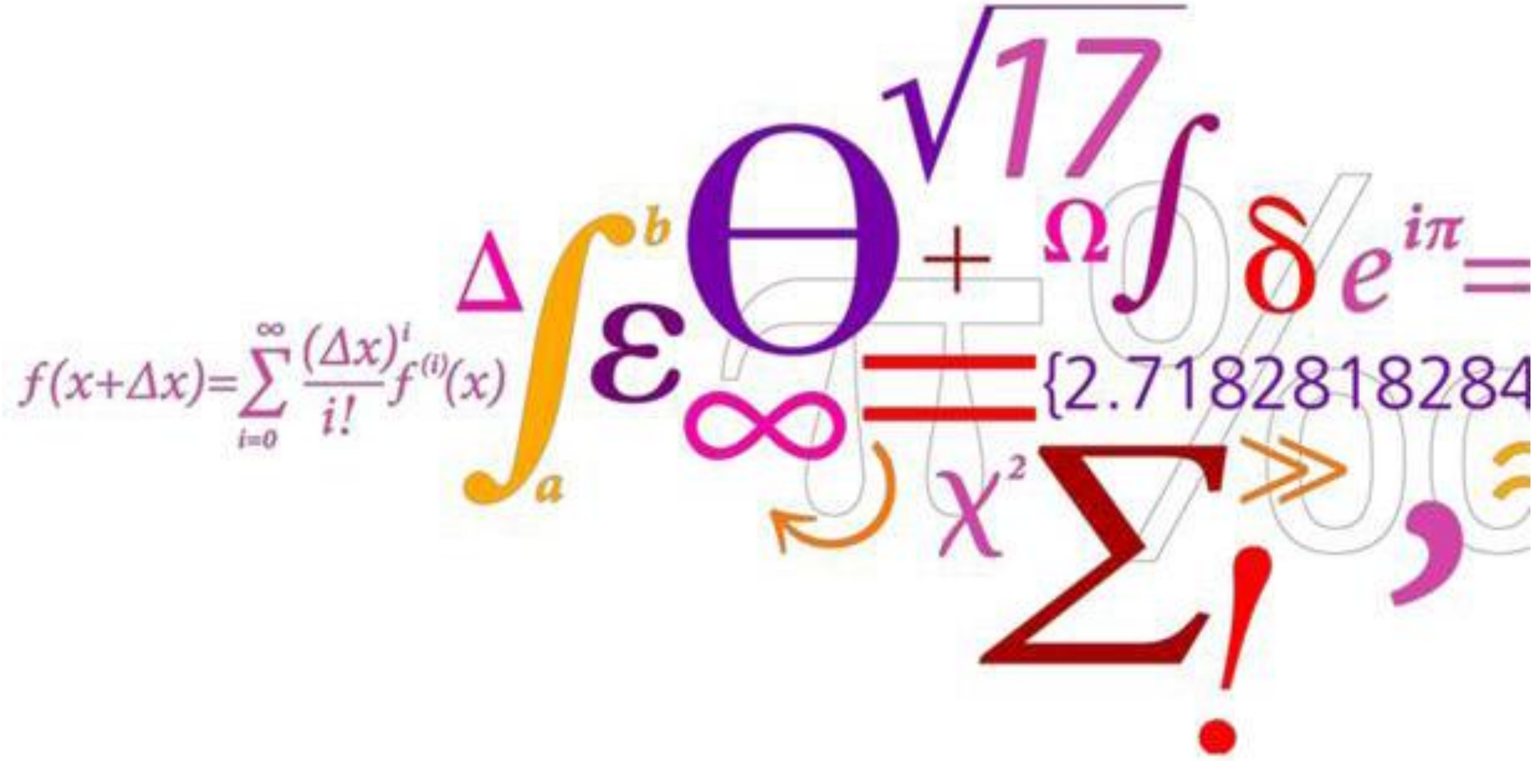
Technical University of Denmark DTU

Integrated Energy Design and use of Building Information Modeling applied in a case study on a daycare institution



Main Report

Master Thesis
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Abstract

Recent application studies in real life projects have proven Building Information Modeling (BIM) to be an effective catalyst in the Integrated Design Process (IDP) to achieve a higher collaboration within the design team, and a better end result. BIM is a concept under continuous development of its every aspect, and perhaps the most import one of these is its applicability in the design phases and the teamwork between the architect and the building service engineer. During the early design stages important decisions affecting a building's sustainability are made. Since buildings have to abide to legal obligations ensuring low energy consumption as part of the strategy to reach the national goal of CO_2 neutrality by the year 2050, it is essential that the design team is provided with the best circumstances to ensure this.

The conventional document based CAD workflow between the architect and the building service engineer causes remodeling and duplication, which can be eliminated through a proper model- and information exchange in a BIM workflow. This thesis investigates the most important differences related to these two workflows for the two mentioned parties. Which benefits, to whom, by which means and with which drawbacks do the BIM workflow involve? Through a case study of a daycare institution optimization of its indoor climate and energy consumption has been performed through the use of IDP in the document based approach as well as the BIM approach. An energy consumption calculation of the daycare institution, made in the conceptual design stage in the simple building analysis tool Be10, indicated that the building meets the goal of fulfilled the BR15 energy requirements. However, dynamic indoor climate simulations in both Bsim and IES<VE> revealed that when fulfilling the indoor climate requirements the energy consumption fell just short of the stated goal. Similar to findings in resent studies, this thesis experienced that the energy consumption made in the dynamic building analysis tool IES<VE> was significantly higher than the results obtained in the simpler Be10 software.

Investigations of this thesis concludes that model exchange from design- to building simulation analysis tools primarily involve direct benefits for the receiver and more indirect for the sender in the form of less rework and a better final project. Several geometry exchanges can minimize remodeling, but exchanges between BIM based programs opens for more opportunities in regard to analysis possibilities, and better interoperability between project participants. All together the BIM approach mainly involves investments in the three areas of: software, training and cooperation, which is also found to comprise its weakest elements. The tested software does not fully provide the sought for exchange capabilities; and aside from proper training, planning is essential to achieve cooperation through BIM and harvest the most benefits, if not, the idea is lost and model remake is cumbersome and extensive. In the end, a short list of suggestions for improvements of this is provided.

Preface

This master thesis has been conducted in the period of August 22nd 2012 to February 26th 2013 including 3 weeks extension of project time due to exterior circumstances. The thesis accounts for 30 ECTS-points and is the conclusion of the Master of Science education at the Technical University of Denmark.

The supervisors of the thesis have been by Jørgen Erik Christensen, Associate professor and Jan Karlshøj, Associate professor and head of department for M.Sc. Architectural Engineering at DTU. The author would like to take this opportunity express his gratitude and thank them both for their help, guidance and inspiration throughout the entire preparation of this thesis. Additionally, the author would like to send thanks to Lasse Brandt and Oliver Franck who has been very helpful with technical issues during the process.

The author initially came around the case study of the thesis through his student job at Esbensen Consulting Engineers. At the start of the thesis, the author had been employed there approx. 3 years and was offered involvement in this case upon request of a thesis case where the integrated design process was used, and with collaboration with Esbensen and the related architect firm. However, it was quickly realized that the case's main design was determined prior to involvement of Esbensen thus also the influence on this would be limited. At the beginning of the project the author was involved in project meetings and made energy calculations in Be10, daylight simulation in Daysim and started on the Bsim simulation model for Esbensen but at the end of the October '12, Esbensen went bankrupt. Afterwards the remains of the company were bought by another consulting company and the case is still under development. However, the bankruptcy effectively cut off the author from any involvement or information of project changes on the real case. This is the reason for the three weeks of extension time of the thesis. The case study in the thesis has taken its basis the actual case's architectural and technical design up until the bankruptcy.

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26th of Februar 2013

Table of Contents

Nomenclature

Abbreviation	Description
AEC industry:	Architecture, Engineering and Construction industry
AHU:	Air Handling Unit
Be10:	Energy frame program developed by the Danish Building Research Institute (SBi)
BCFZIP:	BIM Collaboration Format used for compressed files
BIM:	Building Information Modeling
BCF:	BIM Collaboration Format
BR10:	The Danish Building Regulation 2010
BR15:	Building Regulations expected to be the standard by 2015
Bsim:	Building simulation program developed by the Danish Building Research Institute (SBi)
BSA:	Body Surface Area
BuildingSMART:	International standardization and developing organization for building related software
CAD:	Computer Aided Design
CAV:	Constant Air Volume
CR:	Common Room
Daysim:	Simple daylight simulation tool used in connection with SketchUp
DBW:	Document Based Workflow
DTU:	Technical University of Denmark
FEMDesign:	Finite Element Method Design
gbXML:	Green Building Extensible Markup Language (file format)
HESMOS:	Holistic Energy efficiency Simulation and lifecycle Management Of public use facilities

HVAC:	Heating Ventilation Air Conditioning
IDM:	Information Delivery Manual (information sharing specification used in BIM)
IDP:	Integrated Design Process
IED:	Integrated Energy Design
IES<VE>:	Integrated Environmental Solutions < Virtual Environment > (full scale dynamic simulation tool)
IFC:	Industry Foundation Classes (file format)
ITO:	Information TakeOff (section of the Solibri software)
KG:	Kindergarten
MBW:	Model Based Workflow (the working approach used in BIM)
MDO:	Multi-Disciplinary design Optimization
MVD:	Model View Definitions (used in IDM)
N:	Nursery (common room for nursery kids)
Naviate:	Navigate and Aviate compressed
PV panel:	Photovoltaic panel system (solar cells)
SketchUp:	Sketch drawing program developed by Google
TCD:	Thermal Calculation by Design
VAV:	Variable Air Volume

1 Introduction

There are many demands that modern buildings have to live up to aside from the main purpose of providing shelter form the exterior conditions. The architectural expression, construction principle, cost efficiency and numerous other parameters are all pieces to the puzzle of the overall modern building process, but perhaps the most important aspect in this is how to ensure that a building provides a comfortable indoor climate for its occupants. Aside from definitions of a good indoor climate the building code (BR10) also stipulates that any new or decent size renovation project has to have a low energy consumption determined by the type of building and the low energy class the building is to comply with. Fulfillment of low energy class building regulations can be conducted in a variety of different ways which can be summed up in two categories as either passive design measures or utilization of renewable energy sources.

Recent studies have shown that by using the Integrated Design Process (IDP) in building projects this can lead to considerable advantages during the process and the finished project. By including all parties of a building project from the very beginning, it is possible to interconnect the knowledge and best practice principles within each field of the Architectural, Engineering and Contracting (AEC) industry and through this collaboration take full advantage of the passive design properties available in a given project. When executed correct, the integrated design process can be used as a tool to ensure that the stated low energy goals of a project are reached without jeopardizing any aspects of the project, but it requires a high level of collaboration and willingness to break traditional working habits.

Building Information Modeling (BIM) can be used as a very effective tool and way of collaborating with project partners in the integrated design process. Where IDP prescribes early involvement of all parties in a building project and design decisions made on the basis of iterative design loops, BIM is both the software tools to handle information sharing and much more; it is the mindset that lies behind managing a building process even with conflicting interests. The most efficient BIM process works though ensuring that information of the right standard is shared at the right time to obtain a lean workflow and through a careful planning process and information sharing where model duplication and collisions can be almost eliminated. However, a full integration of BIM into the Danish building industry has yet to come, whether this is due to lack of knowledge (comprehension of its potential), investments, standards, unwillingness to change work habit or simply because a so called paradigm shift of this magnitude takes time to fully incorporate is uncertain.

This thesis will look into what measures are being taken toward higher degree of BIM integration in the AEC industry and what benefits can be gained through the use of BIM in relation to a building's indoor climate and energy consumption. The hypothesis of the thesis is described in the following:

"Utilizing the full potential of BIM and advanced building design simulation tools will enhance the integrated design process related to a building's energy consumption and indoor environment between architects and engineers."

As such there are two goals with thesis:

1. To optimize the indoor climate and energy consumption in a case study of a daycare institution within its framework through IDP with focus on Integrated Energy Design (IED).
2. Investigate the benefits and constraints of the BIM workflow compared to the "conventional" document based workflow in relation the process from the architectural design to indoor climate analysis through different model transfer processes. Included in the investigation is also a comparison of software to be used in these processes and results obtained from these.

This is done for two reasons: 1) optimizing indoor climate and energy consumption within the given limitations to fulfill the goals of the case and 2) investigate what measures have to be done in a BIM approach in order for proper information transfers to work? Which tangible benefits can be proven through BIM as opposed to the conventional document based approach and to whom does this process benefit by e.g. eliminating remodeling? Based on this investigation, potential suggestions of improvements regarding transfer of BIM or merely geometry models from design programs to a building simulation program will be provided.

1.1 Scope of the thesis

Within the broad and complex fields of IDP and BIM delimitations is necessary to stay within the time frame of the thesis. Therefore the focus of the thesis is on the collaboration and information sharing between the architect and building service engineer in order to perform Integrated Energy Design (IED). However, the term IDP will be used throughout the thesis as other considerations also apply. The thesis focuses only on aspects involved with energy and indoor climate in buildings as well as some available tools used to simulate these aspects in the case study. Other aspects are inevitably taken into consideration and briefly described such as the architecture and structural design, but the thesis does not concern direct preparation, design or calculation of any of these fields. In the case study the indoor environment is evaluated on the thermal- and atmospheric indoor climate as well as the available daylight in three selected room types. As BIM is as much a state of mind and way of collaborating with project partners, as it is the tools to be used to facilitate building information models, these two aspects are both addressed in the thesis. The first one is mainly addressed in the state of art section through literature study of the background theory, task groups, legal requirements and initiatives etc. whereas the latter aspect is primarily dealt with in the investigation of BIM model transfer section in the case study. Initially it was the intention that both the BIM mindset and investigation of tools would be addressed in the case study. However, since the actual case has been effectively separated from the thesis new input and collaboration with other project partners are only at a theoretical level after the separation from the actual case.

2 Background

This section describes the circumstances related to the thesis' two main focus points of using IDP to optimize the energy consumption and indoor climate in buildings and incentives to use BIM as to achieve enhance the productivity and reach the project goals. The case of Tranehavevej daycare institution is also briefly described as the basis of the case study in the thesis.

2.1 Motivation

As a good indoor climate in buildings can be relatively easy achieved if unlimited energy resources are available the questing is in fact not how to provide a good indoor climate, but rather how to provide a good climate in an energy efficient manner? The energy efficiency and reduction of CO_2 emissions are almost daily discussed in the media, because in affects us either directly in the way we live our lives or indirectly through society and the world we live in. To main factors are considered in relation to energy efficiency in buildings:

1) Global warming
2) Energy conservation and saving money

The main focus of IDP and BIM is to provide value for the project in which these processes are used for the finished result as well as during the process itself. Their potentials in the AEC industry have been proven to be immense but it is a concept under continued development and full implementation is still associated with hesitation.

2.1.1 Global warming

There is now so comprehensive evidence regarding the reason behind a phenomenon of global warming that scientists can almost certainly say that a raise in the Earth's average temperature it is caused by increasing concentrations of CO_2 in the Earth's atmosphere as a result of increasing use of fossil fuels [IPCC]. Global warming is often considered to be a vital factor in relation to the occurrence of natural disasters and other negative effects of nature. Therefore it is undeniable that some change has to take place toward slowing or reversing this unfortunate effect before it is too late. In Europe, building services account for approx. 40% [IEA, 2009] of the total energy consumption. So if the energy consumption in new buildings and existing ones are reduced, this implies a huge energy saving and CO_2 emission potential. Measures toward this are being done from a legislative point of view step by step every fifth year through the building code, by tightening the allowable energy consumption of new buildings and renovation projects of a decent size.

2.1.2 Energy conservation and saving money

Throughout recent decades the price of fossil fuel based energy has increased significantly as a result of limited energy resources [dst.dk]. Additionally, legislative actions has caused an implementation of taxes on energy and a “punishment” in the energy frame calculation by incorporating a primary energy factor to multiplied on energy used for building operations in order to force builders to design energy efficiently. This means that energy used e.g. in the buildings we construct continue to cost more money as well as damages our environment. According to The Digital Construction (Det Digitale Byggeri) only 1% of the total costs throughout a building’s life is used during its design phases (see figure 2.1). Constructions accounts for roughly 10% of the total costs and the remaining 89% of the total costs are used during the operation and maintenance of the finished building [DDB] & [NTI, 2012]. These 89% of the total costs of a building represent a huge expense for building owners which can be reduced.

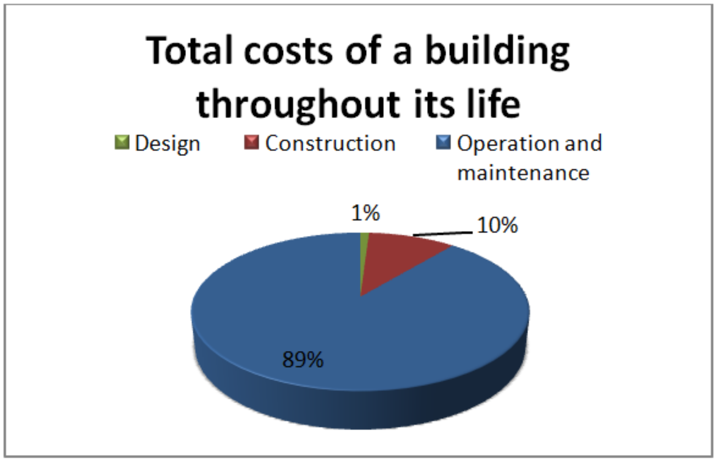


Figure 2.1 - Relation between total cost for design, construction and operation & maintenance throughout the life of a building (Source: [DDB]).

A research project at DTU points to the fact that through the use of IDP in an example with an office building, 50% of the energy used for building operation can be saved by an increase of as little as 7% of the construction costs [DTU-BYG 2008]. The results in this research project were obtained through proper use of passive design properties and good collaboration all the way through the design process of the building. This example illustrates that through little extra effort spend during the least expensive stage in a building’s life it is possible ensure a large future saving in the most expensive operation and maintenance stage of a building’s life.

2.1.3 Motivation to use BIM

Building information modeling is a working approach under constant development and full of potential benefits for all involved parties in the AEC industry [ØG-DDB, 2012]. All around the world task groups, agencies and governments are working on implementing the concept and examples of projects to which this has been applied with success, continue to take place. As BIM is a complex concept still under development, there are sub-sections of this, which can be improved and among these are the interoperability between architect and building service engineer through model exchanges. If conducted correct, this can lead to considerable time savings for the engineer and perhaps the architect as well.

2.2 Integrated Design Process

Briefly described, in the Integrated Design Process it is the intention that all major project partners from architect, engineers, specialists to contractor(s) are assembled from the early conceptual design stage of a project, in order to benefit from their inputs, ideas, needs etc. which can entail the most optimized and coherent final project. Through iterative design loops, a large number of options are investigated within each subject, simultaneously and combinations of these form a space of solutions for the project. These solutions are then be further investigated, evaluated and optimized until the solution which takes account of most subjects and the relevant requirements in the best way, can be selected for further work. According to a recent research project focusing on IED used to optimize building facades to improve building's energy consumption, it was stated that this process involves optimization in three steps:

- Minimizing – concerns the geometrical optimization and utilization of passive properties of a building and its orientation, functional organization, room- and window geometry etc.
- Optimizing –encompasses choice of all building components based on their insulation-, tightness as well as daylight penetration capacities and optimization of the HVAC and artificial lighting.
- Producing- focus on potential for incorporation of renewable energy sources into the building's architecture [Nielsen, M. 2012].

The first two steps reduces the building's energy consumption, and the third step can be used if necessary, for partly self-sufficiency and make the building almost CO_2 neutral. Furthermore, the research project concludes that: "*technical knowledge and inputs are essential to making informed design decisions and do the right thing from the start*" [Nielsen, M. 2012]. This states the core of IDP and IED and reason why it is important to include all parties from the beginning.

2.3 Legal actions and BIM

The new Client Requirements (Bygherre kravene i IKT-Bekentgørelsen 1381), expected to be set into effect April 2013, prescribes the use of information- and communication technology in all government, municipal, regional and publicly owned dwelling projects which exceeds a certain minimum contract price [retsinformation.dk]. In other words, use of Building Information Modeling (BIM) will be increasingly required in these types of projects and possibly be requested by clients in other projects shortly hereafter when the benefits in these kinds of projects are seen and experiences are gained.

Through research projects and real life cases BIM has been demonstrated to potentially involve numerous benefits depending upon the degree of implementation and project size. The higher degree of details in building information models and teamwork in the project team, the more benefits are proven as a result [ØG-DDB, 2012]. However, even isolated use of BIM tools by just one party in a project can involve for that party or for the receiving party of the delivered information. BIM is a concept subject to constant development and improvements both on the software side and through task groups, research projects and real life applications where BIM is applied and tested in all its sub sections. One of these sub section of BIM is the connection between the architect and the building service engineer where correctly transferred building information models can involve significant time saving and elimination of remodeling. But as with other sub sections of BIM, there is still improvements to be done in this context.

2.4 The goal

Along with other European countries Denmark has a goal of being CO_2 neutral by the year 2050 [Energistyrelsen], [Bjerregaard, et al, 2011]. In Copenhagen the vision is to be the first major city in the world to become CO_2 neutral already by the year 2025 [kk.dk]. Initiatives have ensured that a 20% reduction compared to the 2005 emissions is already seen accomplished by 2011. Likewise the municipal of Sønderborg has vision of becoming CO_2 neutral be the year 2029 [projectzero]. These are all visions toward reducing our CO_2 emissions and dependency of fossil fuels in order to reduce the global warming. Among the initiatives to reach these goals are reductions of energy used for building operations.

The goal of IDP is simply to involve all project partners from the first design stage and investigate spaces of solutions through iterative design loops and feedback from all parties to achieve the best possible overall project outcome within the given boundaries.

The goal of using BIM can vary from one project to another, but overall BIM is used to provide value to a project both during the process and to the final outcome. This is to be done through information sharing, reuse of building models, risk sharing, collaboration, collision control, generating quantity lists, sharing of project profits, managing construction etc. As practitioners will become increasingly better at utilizing the benefits that a BIM approach has to offer it is the goal that it will result in more cost-effective, buildable and sustainable buildings [Middlebrooks, R. E.].

2.5 Concerns regarding energy calculation

The Danish building code stipulates that all new buildings must document their energy consumption through an energy frame calculation made through the software program Be10 (previously Be06). This measure is taken to ensure that all new buildings do not exceed the energy consumption stated in the current building code. However, in recent studies [Alilou, et al., 2011], [Petersen, 2012] and [Dethlefesen, et al., 2012] large deviations has been revealed between Be10 calculated energy consumption and measurements on the finished project. Both studies proved measured energy consumption reasonably higher than predicted during the early design phase in Be10. All three of the studies above tested relatively large and complicated office buildings which are exactly the kind of buildings that constitute the main concern related to the use of Be10.

In a recent interview, research director Søren Aggerholm from the Danish Building Research Institute and one of the main creators of Be10 has been credited for saying that; Be10 is only a benchmark tool and it is only to be used for existing buildings, houses and small offices. It was never intended for complicated buildings such as large scale offices. It is the engineers´ responsibility to determine when to apply Be10, and when to apply more detailed tools [Alilou, et al., 2011]. This statement raises concern to the way in which the software is used today as the legal requirement for new simple, as well as more complicated buildings. It is intended as merely a tool for simple benchmark estimations yet in some cases it is being used as a design tool [Alilou, et al., 2011].

The positive aspect of Be10 is that when it is used for the intended purpose (simple projects) Be10 is a very handy tool by which engineers can use at an early stage for benchmarking and with relatively little effort it can provide an estimate of projects energy consumption and overheating hours. The simplicity of its setup and layout offers transparency for easy comparison building projects in between. These features make Be10 suitable in project competition but it should be kept in mind, that the results the program provides are not necessary the actual energy consumption or estimate of overheating hours. To perform more accurate energy calculation a more detailed simulation tools must be used.

2.6 Concerns regarding BIM

As BIM is a concept of as well the tools to be used, and way to manage a work process potentially involving numerous stakeholders, it can often result in a conflict of interests between these, regarding access to and right of specific models. Each party will naturally be most concerned with its own part in the project and tends to hesitate when requested to do extra work for the benefit of another party. Therefore a sense of unity, accomplishment of common goals and more enjoyable building process may be some of the incentives needed to address this hesitation. BIM is a complex concept, which in a way can be expressed as a paradigm shift in the way of managing a building process. What may seem as reluctance to convert to a BIM based workflow in the AEC industry may simply be a result of a time consuming adaptation process, as well as a necessity for fully development of the concept including tools, before practitioners use this in a broader sense. There is little doubt that BIM can involve substantial and tangible benefits [ØG-DDB, 2012] for involved parties, but the main concerns in this context is to develop the tools and foster the collaboration to enable achievement of the desired goals. Interoperability between software programs for opposing uses is difficult because of different needs and support of formats. Improvement of interoperability between software programs, implementation of standards and familiarization with workflows are key issue to increase the use of BIM.

2.7 The investigation

Due to the vast potential of BIM in building processes and the Integrated Design Process in particular, it is found relevant to investigate the current ways of reusing the design model for building simulation analysis through model exchanges and possibly improve these. The investigation is mainly based on the transferring process from the object orientated design software Revit to the advanced dynamic building simulation software IES<VE>, because although the model transfer between these are not strictly fully BIM based, they both support the IFC format and thereby opens for a broad spectrum of BIM based analysis and cooperation possibilities.

2.8 The case study of Tranehavevej daycare institution

The case study of the thesis is a new daycare institution which is to be located on Tranehavevej 15, 2450 København S. Copenhagen Properties (Københavns Ejendomme (KEjd)) and Copenhagen municipality (Københavns Kommune) are the clients on the case [Rubow1]. Rubow Architects, Esbensen Consulting Engineers (energy and indoor climate) and Sloth Møller Consulting Engineers (static) are the consultants assigned for the case. Rubow has the turnkey contract and has hired the other two consultants on the basis of their experience and resumes in related cases. The total Tranehavevej project has a politically approved budget of DKK. 24 million [budget]. This means that it would included within the upcoming Client Requirements (Bygherrekravene/ IKT-Bekentgørelsen 1381) if this had been taken into use, but it is not expected to be so until spring 2013 [retsinformation.dk].

The following is a brief summary of the most significant points from the Building Program (byggeprogrammet) [Rubow1] in relation to this thesis, the full building program can be found in appendix A.

The Tranehavevej daycare institution (Tranehavevej) share its client, contract and design team with another daycare institution located within close distance on Baunehøj Allé. Tranehavevej is to be no more than 1050 m^2 with a maximum capacity of 111 children in six separated rooms. One half of these rooms are for day nursery children age 1-3 (with 12 children and 3 adults in each room) and the other for kindergarten children age 3-6 (with 22 children and 3 adults in each room). In addition, the institution is to encompass all necessary facilities such as toilets, kitchens, storage rooms, an office, wardrobes etc. The maximum allowable height is 25m, however the property site on which the institution will be build is large enough for the required outdoor activities even if the building is to be in only one storey. The open hours of the institution are weekdays from 7 a.m. – 5 p.m.

The building is to be in accordance with requirements of BR15, determined through a Be10 calculation. This goal is to be met through passive design meaning preferably without renewable energy sources, consist of primarily sustainable materials and contain only one fire section. In addition to this a calculation regarding the most economic beneficial energy supply by either a heat pump solution or district heating is to be conducted. This calculation proved that district heating is the most beneficial choice in this case according to Esbensen Consulting Engineers [Esbensen]. An analysis is required for sun/ shade conditions in the common rooms and how to best limit the direct solar radiation in these. The daylight conditions also have to be analyzed in order to optimize this in the common rooms for the sake of saving energy on artificial lighting and providing most natural light as possible. Likewise a transient indoor climate simulation is to be made on the most exposed rooms with permanent working places in the institution.

Architecturally it is the intention that: *"the project is developed with focus on inspiring spatial experiences for children, good working conditions and architectural/ sustainable quality".* This is to be conducted through an intriguing use of special definitions and separations inside and out as well as having a solid architectural appearance in natural materials.

Determination of the location of the various functions has been made in a combination of the architect, client and future users of the building. This has resulted in an organization diagram which can be seen in figure 2.2, has formed the basis for the relative location of each function in the final design of the building [Rubow1].

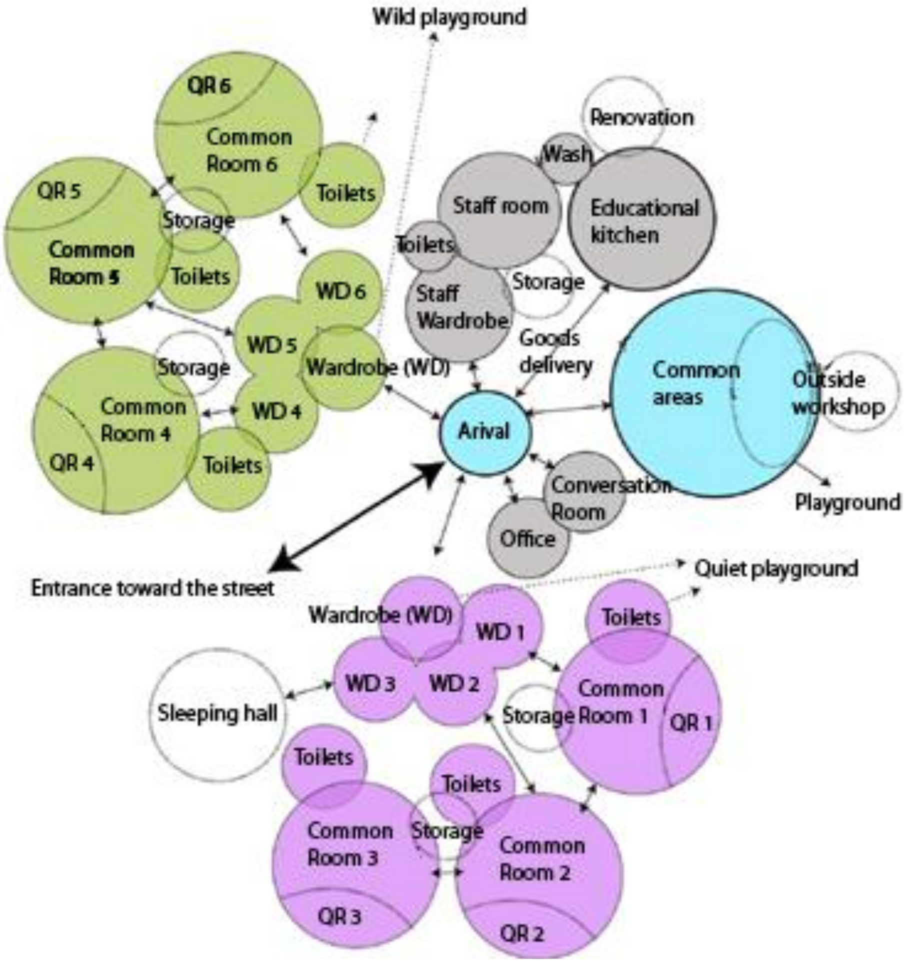


Figure 2.2 – Organization diagram of the relative location of each function in Tranehavevej daycare institution. (Figure: [Rubow1]). (Abbreviations: QR: Quiet room, WD: Wardrobe).

2.8.1 Architecture, static and energy & indoor climate

The following four subsections are outtakes of the most significant architectural, static and energy features of the project at the conceptual design stage, additional information can be found in appendix A and B.

2.8.1.1 Architecture

The architects were hired through a turnkey contract, which means that they were the first to come on board the project and make their initial sketches of the daycare institution based on the building program and the organization diagram in figure 2.2, before the other two consultants got involved. The architects designed the building in one storey with the six common rooms and their associated facilities evenly divided in each end of the building. The rest of the building functions, which accommodate facilities for children and adults in the common rooms in both ends of the building, are conveniently located between these (see ground floor plan figure 2.4). Rubow has chosen to accommodate the requested "*inspiring special experiences*" through a focus on accessibility between outside and inside, as well as related functions, dividing and diversifying separations of rooms and the façade which result in small niches and shaded building parts. In more tangible terms the façade was designed with variations along it i.e. the middle section is wider than the end parts and each common room has wooden pergolas outside this to provide changes in the building façade. These pergolas serve as a visual break/change in the façade as well as providing scattered shadow areas. The roof of the entire one storey building is build with a roof ridge and extruded skylight constructions on top of this. This design approach conflicts with the integrated design process by not including all parts from the beginning, thus these design measures are working slightly against the concept of compacting a building's design to minimize its total transmission area. However, it should be mentioned that the architects did some redesigns of the floor plan layout in order to work toward a more compact design, as well as relocating some skylights in the middle section of the building to provide daylight to rooms without façade access. In figure 2.3 is an axonometric illustration of Tranehavevej daycare institution and figure 2.4 is the plan drawing and facility diagram of the building.

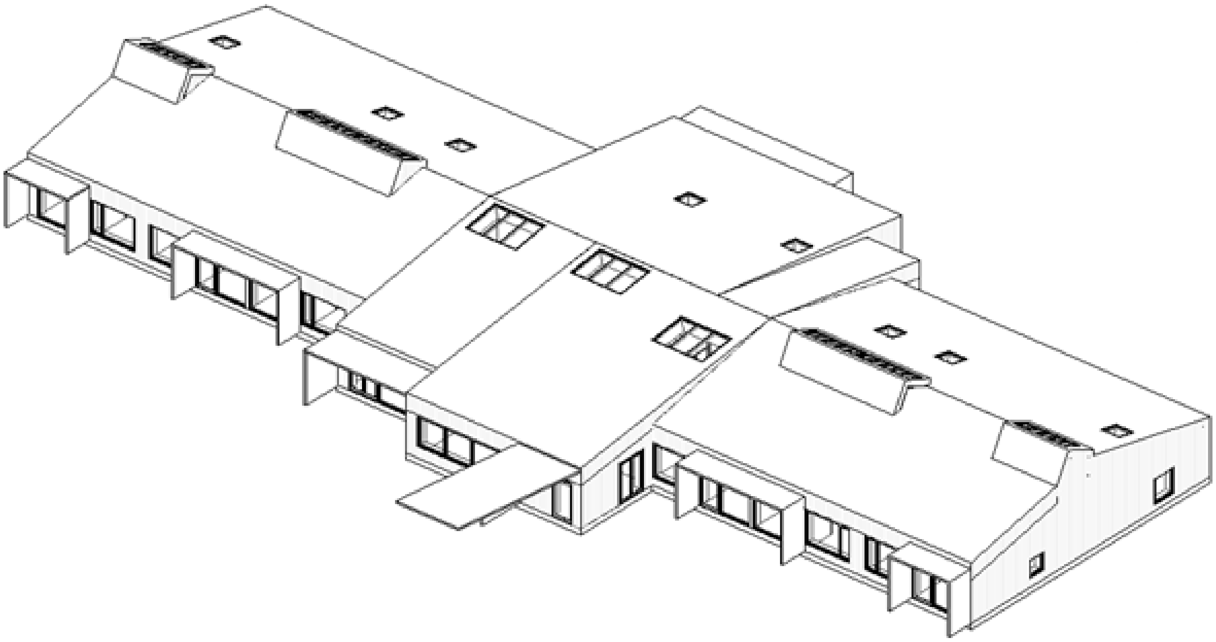
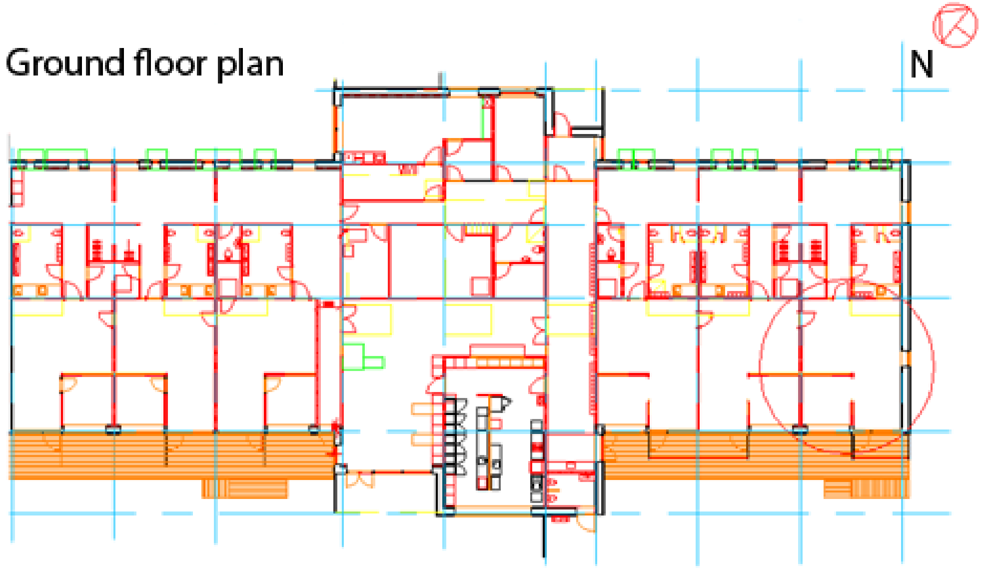
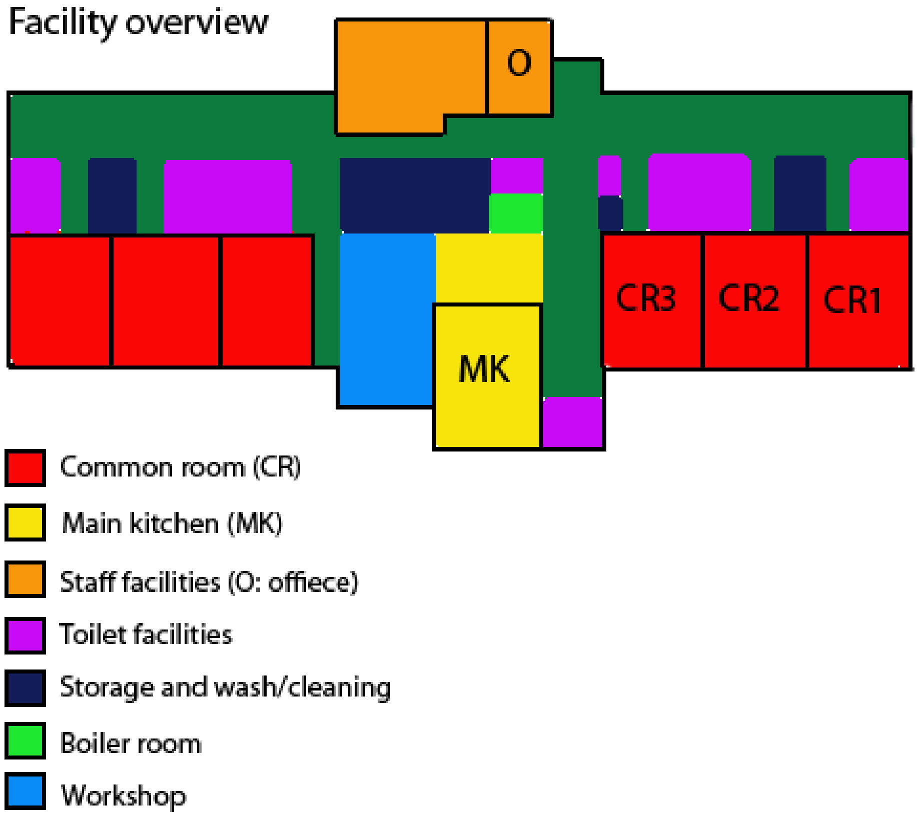


Figure 2.3 - Axonometric view of Tranehavevej daycare institution (north is up).



Ground floor plan



Facility overview

Figure 2.4- Top: ground floor plan of Tranehavevej daycare institution; Bottom: facility overview, the two common rooms (CR1 and CR2) are for kindergarten kids and CR3 is for nursery kids.

Aside from the above, the some of the main exterior architectural features are sets of horizontal lines perpendicular to the length of the building. These are seen in the alignment of the skylight construction with the wooden pergolas outside the southwest façade in each end of the building, these are illustrated in figure 2.5. According to the architects these features provide a vivid and interesting construction with variations along it as opposed to a duller box shape. This design feature should prove to be very essential to Rubow's design and were unchangeable.

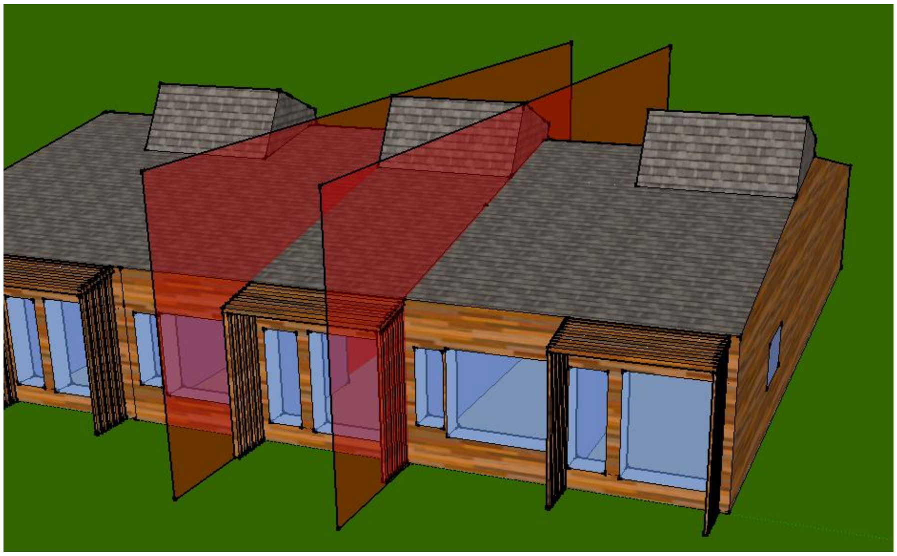


Figure 2.5 - Illustration of the southwest 1/3 of the building with three kindergarten common rooms. The semi-transparent red rectangles outline the invisible horizontal lines on one of the common rooms made by the skylight construction and the wooden pergola, the architect emphasized these as important architectural characteristics.

2.8.1.2 Statics

Starting from the top; roof cassettes are spanning parallel to the length of the building, from here the vertical load is transferred to load carrying wooden beams perpendicular to the length of the roof. From the roof, load carrying wooden cassettes in the facade and elements of lightweight aggregate reinforced concrete in the interior walls, transfers the load to the foundation made of reinforced concrete and from here to the ground. The stabilizing horizontal cassettes in the roof construction and floor slab absorb any horizontal loads and transfer these to the exterior and interior walls and from here to the foundation and soil [Rubow2].

2.8.1.3 Energy and indoor climate

As stated in the building program the objective in terms of energy consumption is to fulfill the requirements stated in the building code for BR15. The atmospheric indoor climate of the building is to comply with indoor quality class II in standard DS/EN 15251 which is to be upheld through increased ventilation rate when the CO_2 concentration approximates 1000 ppm. in any certain room. The Air Handling Unit (AHU) will be located on a separate first floor on top of a storage room in the center part of the building. From here the ventilation ducts are spread out to each end of the building on in an enclosed horizontal ventilation shaft on top of the toilets and storage room facilities (see toilets and storage rooms in figure 2.4. The thermal indoor climate is set according to DS/EN 15251 class II with a minimum temperature for heating 17.5°C with ~1 clo and maximum for cooling 25.5°C with ~ 0.5 clo. In addition, BR10 prescribes limitations for exceeding overheating hours as a maximum of 100 hours > 26°C and 25 hours > 27°C during the open hours of the week days between 7 a.m. -17p.m. These requirements are to be met in the most sustainable way; however it should be kept in mind that since it is a kindergarten and not e.g. an office the occupants are free to move outside as they please if the indoor temperature is too high.

In the summer months there is manually activated natural ventilated through façade windows and skylights in the institution's open hours on the basis of indoor temperature in each room. By using a combination of the façade windows and the skylight it is possible to take advantage of the chimney effect and increase the ventilation rate this way. The natural ventilation rate is determined in the building program to at least $2h^{-1}$ which is used in the case. If this is not enough to maintain the stated thermal requirements the mechanical ventilation will kick in and start increasing the air change rate until a certain limit determined in the case study.

As part of the sustainable strategy heat recovery is used as reheat of the inlet air, three layer energy glass windows are applied and a solar solution is to be determined in the case study. All transmission coefficients are kept at a minimum to minimize the heat loss through the building envelope; these can be seen in the list below.

According to BR10, all permanent working spaces need to have a minimum daylight factor of 2% on any working level. This requirement is complied with through daylight factor simulations in representatives for these rooms by one common room, the main kitchen and the office. (A proposal for incorporation of a green roof on some sections of the building was raised at one point from the architects, but this has been neglected in this thesis).

2.8.1.4 Building envelope

The building envelope described according to Esbensen is listed below and can be found in details in appendix B.

Façade (U-value: 0.1 $W/(m^2*K)$; total thickness: 0.5 m)

- 120 mm light weight concrete
- 350 mm insulation class 34, slotted steel profiles
- Wind plaster
- Ventilated cavity
- Pine wood cladding

Ground slap (U-value: 0.1 $W/(m^2*K)$; total thickness: 0.7 m)

- 150 mm stone fill
- 250 mm insulation class 38
- Concrete deck
- 75 mm rigid insulation class 37 on battens 45 mm every 600 mm
- Linoleum floor

Roof cassettes (prefabricated; U-value: 0.1 $W/(m^2*K)$; total thickness: 0.87 m)

- Asphalt roofing with under laying insulation and 400mm ventilated cavity
- 435 mm rigid insulation class 34 with 100 mm beams every 800 mm
- Acoustic ceiling

Skylight construction (U-value: 1.4 W/(m^2*K); total thickness: 0.39 m)

- Asphalt roofing with under laying insulation and 100 mm ventilated cavity
- 250 mm rigid insulation class 34 with 100 mm beams every 800 mm
- Acoustic ceiling

Windows

- Façade: 3-layer low energy glazing with a center U-value of 0.9 W/(m^2*K), g-value: 0.57 and LT: 73% (an average of 1.0 W/(m^2*K) for windows and door together)
- Skylights: 2-layer solar reflective energy glass with a center U-value of 1.1 W/(m^2*K), g-value: 0.43 and LT: 71%. (See details in appendix C).

(Interior partitioning; total thickness: 0.15 m)

- Lightweight aggregate concrete

(Minor modifications to this have been made in order to fit different input methods, but all the thermal properties remain unchanged).

2.9 Two important formats

2.9.1 IFC format

Industry Foundation Classes (IFC) is an open source standard information exchange format for object orientated models such as BIM [DDB]. In Denmark IFC is the mandatory file format in all building projects which is encompassed by the by the previously introduced Client Requirements and the IKT-publication [bips.dk].
The IFC format has been developed over the past ten years by BuildingSMART which is an international corporation of consultants, software suppliers and universities [bips.dk].
IFC contains semantically predefined content which stipulates a data structure for any part of the building project by categorizing them into separate classes such as ifcWindow, ifcWall etc. This information is then joined to their exact location and number of times they appear in the project. The IFC structures further enables information to be associated with a specific component such as a wall by attaching information about the different layers that together comprises the wall. When a project is delivered in IFC format through a BIM model the project

can contain information of a certain information level attached to the geometry model and accessible to be used by the receiver. This creates a good coherence between various subject specific models, eliminates redrawing and improves the information flow and interoperability between business partners [DDB].

2.9.2 GbXML format

Green Building Extensible Markup Language (gbXML) is a Schema/ file format which contains information about a building project stored in the building information model and developed to enable transfer between various programs [gbXML]. The file format assists the interoperability between a wide range of software programs such as Autodesk, IES<VE>, Ecotech, Bentley etc. This means that if a 3D model is created correct according to certain predefined guidelines, the geometry information stored in an 3D model can be exported from e.g. Revit Architecture/MEP through the Revit to IES<VE> plug-in developed by IES into their software for building analysis. The file format is developed to enhance sustainable buildings achieving their goals. Its interoperability eliminates the need to redraw geometries in analysis tools, assists design teams to make the best possible use of BIM and thereby saves the involved companies money in the process [IES BIM 2011]. However, as of now (at least with IES) gbXML file format is limited to information transfer from design to analysis tool and not the other way around, which could be convenient after a suitable solution is found in the analysis tool. IES admits that the converting process by which the gbXML format is used is not perfect and they are constantly improving on this as well as looking into the possibly of using the IFC standard instead sometime in the future [IES BIM 2011].

3 State of the art

3.1 Building Information Modeling

As Building Information Modeling (BIM) is a very broad and relatively complex concept this thesis will not go into details concerning all aspects of BIM. This thesis will primarily focus on aspects of BIM related to design and planning phases in regard to mainly energy and indoor climate issues in buildings. Issues such as execution and operation are briefly touched upon for the sake of encompassing some of the countless opportunities of BIM. This section of the report investigates the current state of BIM as well as its background/ theory, workflow, information levels, challenges, benefits and incentives of BIM in relation to the Integrated Design Process, and is giving one example of upcoming opportunities of BIM. However, this section should not be regarded as a complete description of this sub section of BIM, but rather introduction to most important characteristics, and aspects related to this thesis. In later sections of the thesis, the practical use of BIM will be applied on a case study in relation to the main focus of the thesis.

3.1.1 Background

BIM is the latest development of CAD technologies used to design, manage and share information of building projects with project partners [Vestergaard, 2011]. In this context the AEC industry is sometimes referred to as having gone through two major transitions or paradigm shifts [ØG-DDB, 2012]. The first major shift was going from manual drawing production toward a 2D CAD Document Based Workflow (DBW), where drawings are produced and send electronically, but often printed out by the receiver and the information is handled manually. Later this developed into production of 3D geometry with attributes handled separately and then going toward the second major shift, where object oriented *n*D models[1] are "containers" of all relevant information of a certain project, shared with project partners [Vestergaard, 2011]. The coupling of the latter two, models and information attributes, is really the key concept behind BIM and a Model Based Workflow (MBW), which is the main reason for BIM's wide applicability- but also its complexity. Beneath is a list of the main differences between the 2D CAD approach and the BIM approach according to Statsbygg in Norway.

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[1] *n*D models refers to the fact that a 3D model may contain more information than building component attributes, hence 4D models includes a time schedule, 5D models cost estimations and 6D model is the "as build" model intended for handover to the owner for operation and maintenance [Wiki].

Table 3.1 – Overview of differences between 2D CAD and BIM [Statsbygg].

	2D CAD	nD BIM
Concept:	Drawing	Model
Operation mode:	Closed source software	Can be open or closed
Data format:	DWG and similar	IFC
Working tools:	2D-CAD	nD-BIM
Procedures:	Drawing	Modeling
Contract:	Conflict Driven	Risk Sharing
Mindset:	My Deliverable	Our Deliverable
Project partners:	Producing	Collaborating

In relation to table 3.1 it should be mentioned that the list reflect the way in which the Norwegian consultant agency Statsbygg describes the differences between the two workflows. However, as BIM is a very complicated concept, which may be applied in a range of different ways and levels, not every part of the table may be relevant in all cases. To define BIM a little better it may be divided into two main concepts:

1) A reinvention of collaboration between participants and managing a project (mindset).
2) An object orientated parametric design approach that enables information sharing (software) [Schoch, 2013].

Together these two concepts comprise what will henceforth be referred to as the BIM workflow. In an ideal and fully integrated BIM workflow, professionals from all fields involved collaborates from the beginning and throughout the project to ensure that information of the right standard is shared, *n*D building models are compatible and handled in and intelligent way, so all participants can gain from this information and thereby bring value to the project [OpenBIM]. At least this is the main intention behind BIM, but BIM itself does not suddenly provide the answers to all the problems. Often participants are mostly interested in what they can gain through use of BIM and are hesitant to do extra work for others, if they cannot see the direct benefit of this for themselves. BIM does not guarantee collaboration, all participants has to be willing to invest extra to gain extra through information, risk and profit sharing. This digital information sharing can increase the project value in three main areas:

1) Construction of models, where data like e.g. geometry and attributes can be recycled and shared.
2) Verification and tests of model properties are simulated for various purposes.
3) Documentation for construction and use of the container of information that can be used for operation and maintenance. [Vestergaard, 2011].

In this way BIM very well links to the integrated design process. The goals of these two concepts are similar and BIM can be used as a powerful tool and way of managing a project which uses the integrated design process. It should be mentioned that although BIM is still under development, it has been proven, as will be described later that if implemented and executed properly, use of a BIM workflow can provide significant benefits for participants and the final product. These benefits are not only in the form of financial savings, but also quality assurance and collision control, whereby *"Errors can be eliminated in bits and bytes and not in steel and concrete"* [statsbygg]. By this is meant that if collisions and inconsistencies are discovered in the design phases, fewer corrections will have to be made on the construction site, which potentially involves a respective cost saving and possibly a better building.

3.1.2 Model types and information levels

When integrated BIM is used in a project, it involves many aspects that are normally not possible to perform (documentations, simulations, structural analysis etc.) in one program. Instead an abundance of software programs are available to be used within each activity to perform different tasks. Det Digitale Byggeri (The Digital Construction) distinguishes between two model terms "aggregate model" (fællesmodel) and "discipline model" (fagmodel) [DDB]. Where the first type is usually a reference model (often architectural model) all project parties can refer to, the second type is specific to each discipline and contains only information relevant to one professional field [OpenBIM].

In order to describe and keep track of the detailing level models are commonly categorized according to their information level according to 3D working method (3D Arbejdsmetode) in The Digital Construction. An illustration of this is found in figure 3.1.

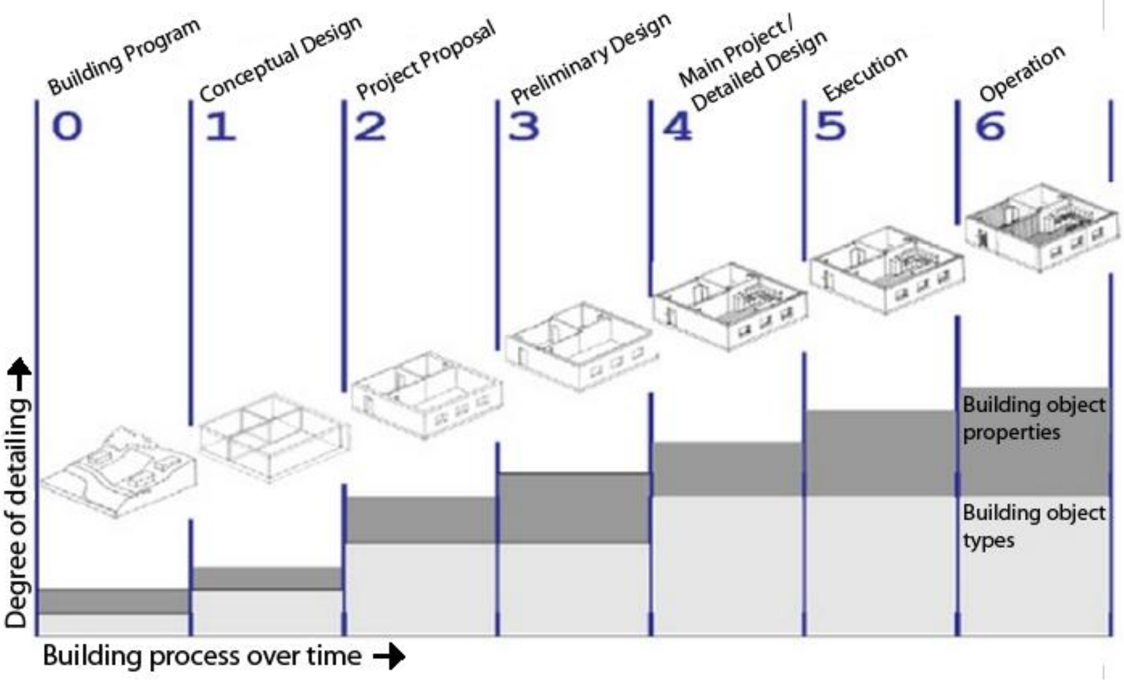

Figure 3.1 - Information levels of building information models. (Figure: [DDB] (see larger image in appendix D).

In figure 3.1 information level 0 comprise the clients requirements which goes ahead of the design and modeling process, after that the following six levels describes an increasing level of detail and number of building components with more accurate information applied throughout the building process [DDB]. The following is a short description of each information level and in which process stages each is applied:

Level 0 – Client requirements described in the building program. Can contain volumes and terrain.

Level 1 – Conceptual design phase defines the building´s general inner and outer geometry and overall functionality.

Level 2 – Project proposal for decision making. Describes building components on a general level of e.g. exterior/interior walls, windows, slaps, roof etc. Each component has a form and a location.

Level 3 – Preliminary project forms the basis for authority treatment. The model defines the building´s general construction with the appropriate information.

Level 4 – Detailed design. Forms the basis for tendering, cost estimations etc. and information on building components in order to make the necessary drawings and quantities.

Level 5 – Forms the basis for the execution. The building model has to include specifications on building components and properties to be used in the project.

Level 6 – Final model used for operation and maintenance, has to be modeled “as constructed” [DDB].

3.1.3 Implementation challenges

Since BIM is both management of a workflow and utilization of various software programs it is not something that can just be bought. A company may buy a software package, fit for their professional needs, but knowledge on how to use and take advantage of the many opportunities that a BIM workflow may involve has to be gained through examples and experiences. According to a research project, three main investment areas common for all parties at any stage of the building process are necessary for a company to be successful with BIM. These investments are in the following:

1) The proper BIM software
2) Training and qualification of employees
3) Cooperation within the company as well as other companies. [ØG-DDB, 2012].

The same research project concluded that the largest investment area of the three mentioned was not in purchasing of software, but rather in educating staff and often expenses for cooperation are neglected [ØG-DDB, 2012]. Additionally, Cuneco which is the center for productivity in construction in Denmark concludes in a “requirement analysis” of BIM in the AEC industry that: *“the (AEC) industry’s mental attitude and the cultural change is the main problem in regard to implementing a BIM workflow (Det Digitale Byggeri), more that missing standards and tools”* [Cuneco, 2012]. This emphasizes that especially the change of mindset is what causes hesitation by the industry. Companies naturally want to know what they go into, how to do it and what they can expect in return for their investment.

The progress of BIM implementation in the AEC industry can be approximately illustrated by Gartner’s hype curve seen in figure 3.2.

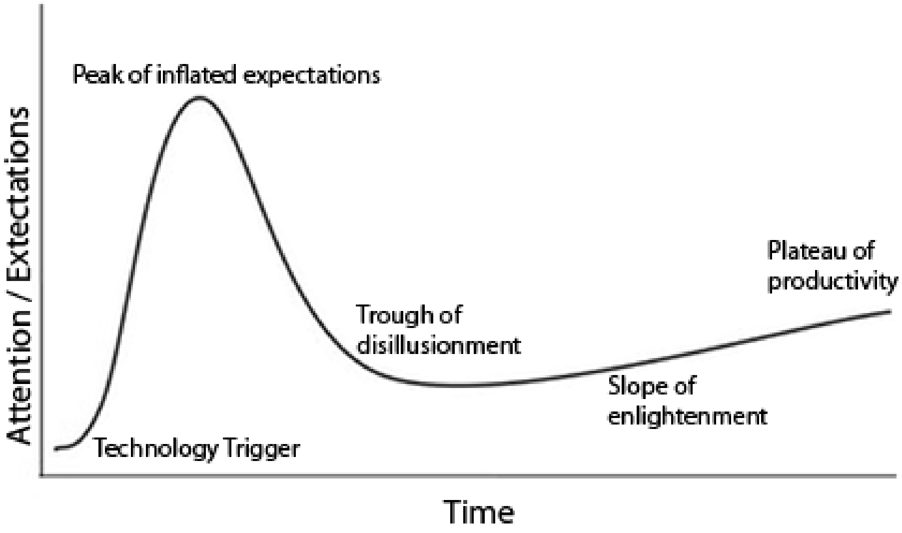

Figure 3.2 – The Gartner hype curve. Gartner is an information technology research and advisory company in Stamford. (Figure: [sciencedirect]. See larger image in appendix D).

Figure 3.2 depicts a graph common for many new technologies. When the technology (in this context BIM) is first introduced it causes a steep curve increase of expectations until “peak of inflated expectations” where it is discovered that this technology also contains constraints and drawbacks. This causes the curve to decrease until “trough of disillusionment” which is a low point of attention and applications which continue until “slope of enlightenment” where information on how to implement and manage BIM is tested and standards are made accessible. This results in a slowly but steady increase of attention to “plateau of productivity” because of productivity increase following the knowledge and experiences gained in the previous stage by e.g. independent task groups and research projects.

So thanks to initiatives to promote BIM (more on this in coming sections) we are now in Denmark somewhere on the “slope of enlightenment” toward “plateau of productivity”. Many companies are starting to see and feel the benefits of a BIM workflow which gives incentive for other companies to follow along if they want to be able to compete and offer the same services to their clients [ØG-DDB, 2012].

Yet another challenge worth mentioning in relation to implementation of BIM and fully use of IDP is the fact that in some sense the AEC industry is relatively conservative and reluctant in relation to new working approaches [autodesk.com]. This is illustrated in the MacLeamy Curve which depicts the main difference between a conventional (DBW) and a BuildingSMARTs (MBW) in terms of where the majority of the effort is located. The MacLeamy Curve is depicted in figure 3.3.

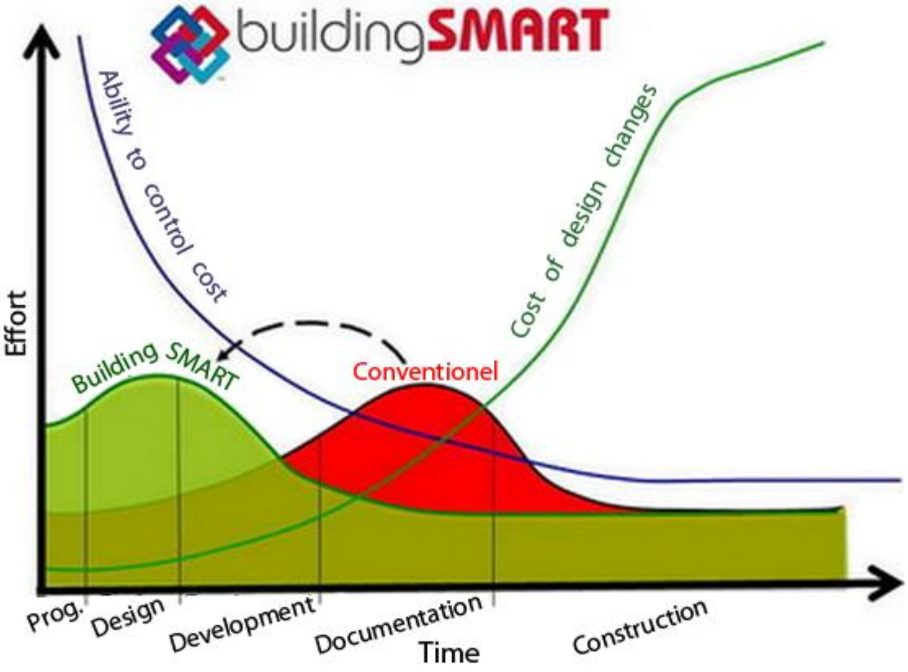

Figure 3.3- MacLeamy Curve illustrating the conventional building processes and the BIM process in relation to time, effort, ability to control costs and cost of design changes. (Figure: [BuildingSMART.com], see larger image in appendix D).

According to the MacLeamy Curve in figure 3.3, because an increasing amount of details are documented throughout the project the ability to change is largest in the beginning of this and the costs of design changes increases rapidly as the project progresses. Finally the “cost of design changes” curve peaks in the construction phase because a design change here may cause loss of loads of work and delays. The figure also depict that the largest amount effort in a conventional process is reserved for documentation after a building is designed, because this is often where the majority of the payment is made to the design team. The conventional approach is not very effective in terms of getting the best building result in the end. Instead in the IDP approach through the use of BIM the largest effort is shifted to the design and development stages which provide more time an effort to be put into development and testing of alternatives [MacLeamy, 2010]. With more effort shifted toward the design and development stages more room is given to the iterative design loops which is essential in the IDP. However, for this shifting of effort to take place a shifting in the percentage of the total budget has to follow along so the design team is paid for their extra effort in the beginning of the design process, if not their risk is too high if they are not involved in subsequent stages [ØG-DDB 2012].

3.1.4 Incentives for BIM and legal requirements

As mentioned previously various independent Danish task groups such as Cuneco, Det Digitale Byggeri (The Digital Construction), BIMbyen (BIMcity) are doing a large amount of research and standardization work in Denmark toward increasing the awareness and use of BIM in all phases. This is done by providing examples on how to manage BIM and what benefits the workflow can provide. Among these standardizations are the Cuneco Classification System (CCS) replacing

Dansk Bygge Klassifikation (DBK) as the new Danish standard in building classification systems which is also internationally compatible [cuneco.dk]. The CCS structures and classifies building objectives and assigns relevant information to these objects according to ISO standards for later management [NTI, 2012].

Also internationally there are BIM task groups and awareness incentives. In the UK the government announced an intention in 2011, to require use of collaborative 3D BIM in its projects by 2016, up to at least information level 2 [Wiki]. This is aided the UK by the BIM Task Group, which states that they bring expertise from industry, government, public sector and institutes to support and develop BIM [bimtaskgroup]. Also in the UK, NBS has developed The National BIM Library, which is a free downloadable BIM library with more than 400 generic objects covering all sorts of building components such as walls, roof and floors to be used throughout the industry [nbl.com]. In other countries likewise initiatives are seen in Canada with the Institute of BIM in Canada, and in Norway an alliance between six large consulting firms is formed to increase the use of BIM [Wiki]. Finland is a pioneer in terms of implementation of BIM because of its industry increasing use of a model based working approach since back in the 1970’es. However, the perhaps most important initiative of BIM is the international BuildinSMART task group, which has branches into industries in many countries and helps these with a large range of aspects related to BIM [BuildingSMART.com].

Aside from these task groups and companies, there are research projects such as “Measuring of economic benefits of the Digital Construction” (Måling af økonomiske gevinster ved Det Digitale Byggeri” [ØG-DDB, 2012] which is a large field analysis from the Danish AEC industry. In this research project, four different cases with four different actors of varying sizes from the industry were inspected, to see what actual tangible benefits they could measure through BIM workflow regardless of the company’s prior BIM experience and implementation degree. The four cases in the research project were:

1) BIM at a small architectural firm
2) BIM at a large consulting engineer company
3) BIM at an operator and construction and operator consultant
4) BIM at a large contraction company

In all four cases a hybrid approach of the conventional DBW approach was used together with the BIM (MBW) approach and in all four cases substantial benefits were demonstrated in several aspects of the projects compared to using only the DBW. However, with such distinct different ways of working as DBW and MBW, even if they can be combined, the right circumstance has to be in place before the BIM working approach is adopted in a broader perspective in the AEC industry. According to [ØG-DDB 2012], aside from software which can produce and handle these 3D models, some or all of the following circumstances has to be in place:

1) Legislative requirements for transition (Client Requirements[2])
2) Standardizations
3) Motivation in the form of tangible benefits now and in the future[3]
4) The right knowhow to make use of the new opportunities this approach can deliver (further training for existing employees and/or recruitment of new employees)
5) Real examples/ case studies illustrating how to implement and which pros and cons are involved [ØG-DDB 2012].

So if all this is in place, what are the benefits? According to [ØG-DDB, 2012] the four case studies all demonstrated benefits exceeding the company's investment, when looking on company and industry level and not just a single project. These benefits of implementation of BIM in one company can be measured three different places:

1) Directly in the current project (project level)
2) Indirectly in another project in the same company (company level)
3) Derived in another company and possibly in other projects (sector/ community level).

This means that if one company implements a BIM workflow it may provide benefits directly or indirectly in that company because of e.g. recycling, quantity takeoffs etc., but when information is shared these benefits can also be measured at the receiving end. If all benefits of BIM at all stages of the building industry are included from cradle to cradle, there would be countless, but among the more tangible and important ones in this context are: better design, better model transfer to simulation software, collision control, extraction of data, increased productivity, less duplication of models, reduced costs, fewer mistakes, project coordination, faster delivery, better end result in regard to lower energy consumption, better indoor climate and a higher user satisfaction [ØG-DDB, 2012].

Finally the research project concluded that because conventional approach and the BIM approach can be combined the change does not need to be a paradigm shift, the transition can take place gradually. However, it was discovered that the largest amounts of benefits were present in cases with the largest degree of implementation. Indeed, all actors in the four cases preferred the BIM approach to the conventional approach after having tried it [ØG-DDB, 2012]. This research project serves as encouragement toward implementation of BIM in the AEC industry in Denmark in a broader perspective. In addition, the project also provides accessible examples of how the four different actors in the four cases applied BIM in a project in their company with meticulous details and experiences gained.

Legislative requirements are also involved in BIM by not only encouraging its use, but by making it mandatory by the law. Such requirements are set forth in the Client Requirements (Bygherrekravene/ IKT-Bekentgørelsen 1381- krav til anvendelse af Informations- og

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[2] (See more information in the Client Requirements (IKT-Bekentgørelsen 1381) later).
[3] (See benefits measured in ØG-DDB later).

Kommunikationteknologi i statsligt byggeri). The official start date for the updated requirements has been delayed several times, and is now expected to be postponed until start of April 2013[4]. In brief these requirements concern use of information- and communication technology in government building projects with a contract price that exceeds DKK 5 million and in municipal; regional and public owned dwellings with contract prices exceeding DDK. 20 million for both new building projects and renovations [retsinformation.dk], [NTI, 2012]. Furthermore, the Client Requirement states use of the following in the above mentioned situations:

1) Use of CCS
2) Use of a project web in building projects
3) Use of digital building models in 3D (BIM)
4) Use of digital tendering in trade and main contracts
5) Use of digital delivery of case, operation and maintenance and operation information
   [retsinformation.dk], [NTI, 2012].

These are a few of the main requirements from the government and various stakeholders within the AEC industry toward encouraging use of BIM. However, even though it is possible to use lonely BIM as just one party in a project, this will only gain access to a small portion of the benefits that BIM can offer. If a larger portion of the benefits is to be obtained it requires a high level of collaboration within the entire project team. This is not easily implemented or managed which is why Information Delivery Manuals are applied.

3.2 Information Delivery Manual

3.2.1 Background

As mentioned previously a fundamental element in the BIM workflow is the collaboration between project partners through digital information sharing. This sharing of information ideally follows what is called an Information Delivery Manual (IDM), which is not always implemented but it basically describes the sub processes going on throughout a project, which partners (architect, building services engineer etc.) are involved and which exchange requirements are set for each information delivery in a building project in a standardized manner [bips.dk]. An IDM is a process map which identifies when particular types of information are required during either a building process or operation of a built asset [BuildingSMART.org]. In addition, an IDM further presents detailed specifications of the information and time of which each individual project partner needs to provide this and combines information required in associated activities such as energy analysis, cost estimations etc. [BuildingSMART.org]. *"The main purpose of an information delivery manual is to make sure that the relevant data are communicated in such a way they can be interpreted by the software at the receiving side"* [BuildingSMART.org]. Thereby an IDM's main purpose is to provide value through a structured, standardized and well planned Information sharing process in a certain project. For more information and standards on IDMs ISO 29481-1:2010 "Building

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[4] Government building project with contracts exceeding DKK 20 million has been bound by these requirements since 2009.

information modeling – Information delivery manual – Part 1: Methodology and format" developed by BuildingSMART can be referred to. In a BIM project it may be chosen to use a premade IDM or create a new one because the content may vary from one, building project to another, in order for it to be most suitable.

Each exchange stage in an IDM results in a set of exchange requirements. These are then applied in a single or a group of Model View Definitions (MVD) related to the project [BuildingSMART.org]. Where the IDM specifies information delivery in terms of who is involved and when exchanges/sharing of information takes place, the MVD translates the exchange requirements into software requirements. This translation from exchange- to software requirements are made to ensure that there is software to support the exchange requirements in the form of an IFC-specific map which defines how each exchange can be accomplished using IFC [Grobler, F., 2010]. For a MVD to be recognized by BuildingSMART as an approved standard, it has to support at least two software programs – the sender and receiver of the exchange [BSMART 2012].

All though very important in the BIM workflow, the exact generation and execution of IDM and MVD are a bit complex, which is why an example is given in the following.

Example

The following example of how an IDM can be formed is from a research project with the title "**H**olistic **E**nergy Efficiency **S**imulation and Lifecycle **M**anagement **O**f Public Use **F**acilitieS" (HESMOS). Figure 3.4 depicts where each major step in this IDM example is and on the following page is an explanation of each individual stage.

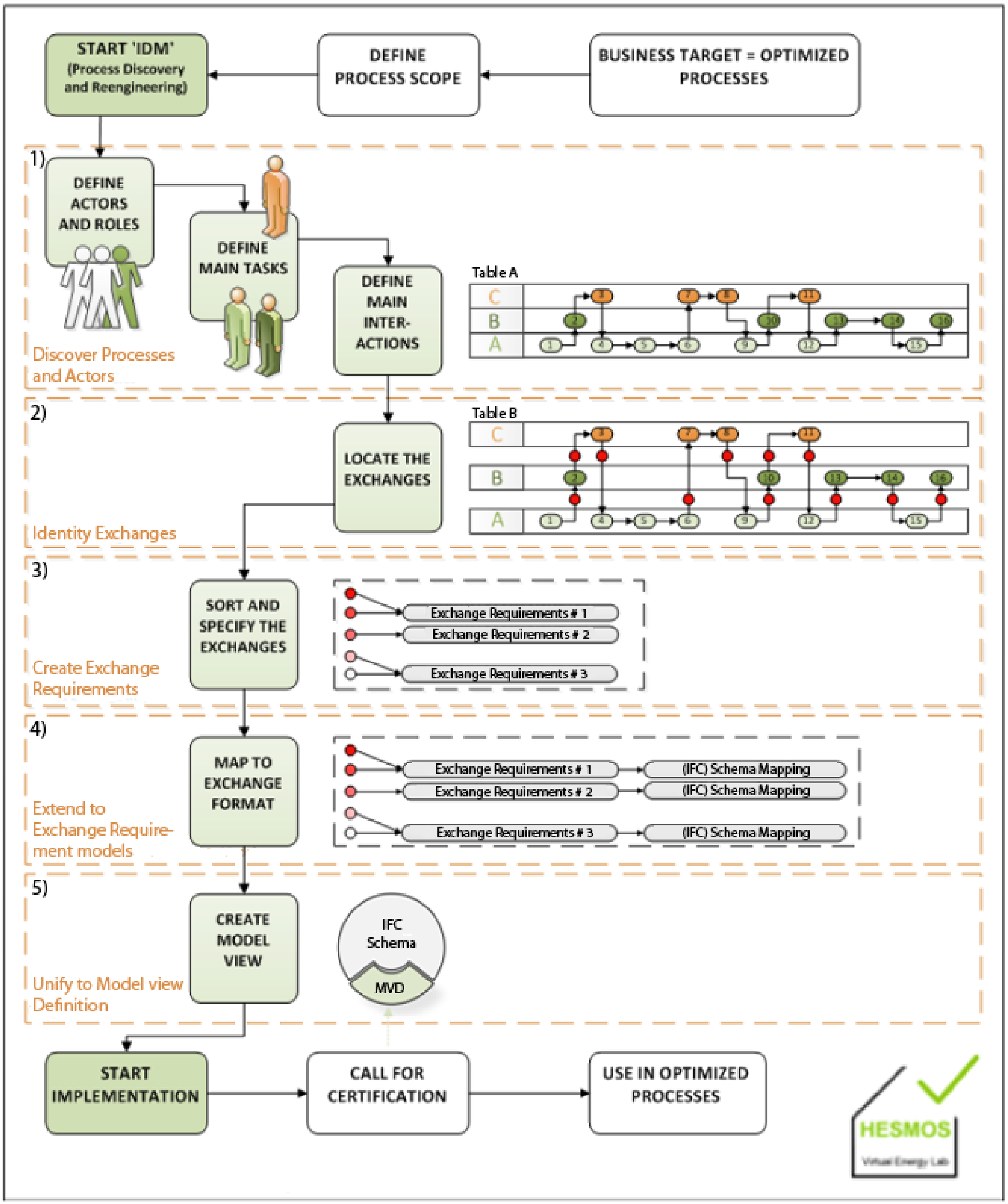


Figure 3.4- General process of Information Delivery Manual (IDM) (figure: [HESMOS] see larger image in appendix D).

1) Discover processes and actors which are defined by their roles and an example of an information process is symbolized in table A (in figure 3.4) with three project partners in each their horizontal lane (A, B & C). The colored boxes in each lane illustrate where an action needs to take place by the corresponding actor and the arrows illustrate who is the sender and receiver in each delivery.

2) Identify exchanges: The main iterative processes that require exchanges are symbolized by red circles in table B in figure 3.4.
3) Create exchange requirements that determine what is needed at each exchange stage for the information to be usable by the subsequent project partner to perform his/her tasks.
4) Extend and combine these requirements to exchangeable requirement models.
5) Unify to a Model View Definitions (MVD), which explains the exact file format at information level of each individual exchange in the IDM [HESMOS].

Following the creation of the IDM this has to be certified by BuildingSMART prior to use as standard in an optimized process.

3.3 Surveys regarding the use of BIM in Europe

With all the fuss about BIM and reasons for and against utilization of it, an investigation on how well BIM is adopted in the AEC industry is of interest. Information on this will give indication on how well implemented BIM is and whether all the work from task groups and so forth have paid off. Much of the information above about BIM is more or less universal for many countries in the Western World or at least in Europe including standardizations and workflow. However, the previously mentioned Client Requirements are based on Danish requirements as well as the four case studies in research project [ØG-DDB, 2012] are taken from the Danish AEC industry. It has not been possible to obtain a relatively recent survey regarding the adaptation of BIM exclusively in Denmark, rather the following information are from surveys regarding the British [National BIM Library, 2012] and the Western Europe [McGraw & Hill, 2010] AEC industry in a broader sense. The McGraw and Hill survey numbers are mainly based on surveys conducted in England, France and Germany. Since these two surveys are not exclusively on the Danish AEC industry and they are one to two years old the numbers cannot be considered to be exact replica of the current situation in the Danish industry, but they may serve as indications and possibly direction of development.

According to the National BIM Library survey of the entire AEC industry with over 1000 respondents they found that 48% of these were only just aware of BIM prior to the survey, 31% were aware and current users of BIM but an entire 21% were unaware of BIM. This indicates that there is still considerable amount of work to be done in regards to increasing the awareness of BIM and with just about 1/3 of the respondents stating they are using BIM in some projects, there is still a long way to go until the entire industry has caught up. For the sake of raising awareness and increasing the use of BIM, the same survey fortunately points out that the percentage of users of BIM (31% in 2011) had increased from just 13% in 2010 which indicates an increase in one year by more than 100%. Of those who indicated awareness of BIM, 3/4 expected to be using BIM within one year in some projects and 19 out of 20 within five years. These are interesting numbers, but should be considered as only indicative as outside circumstances such as the financial crisis may cause change in this. The survey indicated that the financial crisis was a factor causing hesitations in regard to BIM throughout the industry [National BIM Library, 2012]. The McGraw & Hill survey indicates similar situation for Western

Europe with 36% of their respondents having adopted BIM and in North America this development is even more immense with 17% in BIM adaptation in 2007 to 70% in 2012 (from a follow-up article, October 2012 [Construction.com]).

The two surveys conclude that there are practitioners, who have adopted BIM in all stages of the AEC industry, but it is not divided evenly. Out of the 36% who answered that they use BIM to some extend in some of their projects approx. 1/2 of these were architects, a little over 1/3 were engineers roughly 1/5 were contractors. Out of these 45% consider themselves to be advanced or expert users [McGraw & Hill, 2010]. Both surveys show positive responses from users of BIM whether they are new users of advanced the majority responded that BIM works better than anticipated. The respondents further explain that BIM provides: increases productivity due to easy retrieval of information (67%), increased cost efficiency (65%) and speed of delivery (59%) and only 2% of the respondents replied that they do not prefer to work with BIM [National BIM Library, 2012]. The National BIM Library survey ends up by stating that the year before the survey was conducted they suggested: *"BIM to be the future… It looks like it might pay to get on board sooner rather than later"*, and concludes that *"BIM is increasingly the present and it might be best not to get left behind"*.

Although these two surveys are not taken from the Danish AEC industry they do express a general positive attitude toward the use of BIM. Furthermore, it seems that even though the adaptation throughout the industry is not evenly distributed among architects, engineers and contractors it is growing popularity by the year and practitioners are positive about the benefits this working approach can lead to.

3.4 Example of future opportunities with BIM

3.4.1 Background

As it was mentioned in the theory section, BIM is not a completely finished and ready to use product or working approach. Various aspects usable in a BIM context are constantly being developed and improved upon and one of those ideas that have been tested and are starting to gain interests amongst software developers are the so called "Cloud Network" [IES BIM 2011]. A Cloud Network uses a method referred to as Multi-Disciplinary design Optimization (MDO), in which one main model is used for a wide range of simulations on a network of computers. By utilizing the processing power of many computers as opposed to just a few as conventionally, the design team can investigate many different scenarios simultaneously and make their final design choice based on a much more informative background [IES BIM 2011]. The process works by setting a large number of computers to simulate on the same building project, each of these with small variations on a predefined set of parameters within a certain interval and with specified design goals. This way the predefined parameters are simulated with a large number of combinations, some of which might not have been investigated in the traditional manner, but could potentially include a favorable solution [Stanford CIFE].

3.4.2 Example

One example of utilization of a Cloud Network is in a housing project at Stanford University. The project objective was to construct a number of new housing buildings on the campus area which aside from the traditional functions ought to be minimizing life-cycle costs and carbon footprint. The design team used these two objectives to optimize their simulations according to with the following set of variable parameters to work with:

- Number of buildings (3 to 4)
- Number of stories (5 to 8)
- Shape of building – dimensions of each side of a **H**-shaped building
- Building orientation (0-360°)

(Other cases might involve investigation of completely different variables)

The following were constants that the final design had to fulfill:

- Gross floor area of 1.500 m^2
- Distance to site perimeter: >20 m
- Distance between buildings: >20 m

These variables and constants combined represents the project's design space (number of design options) to $1.46*10^{11}$ [Stanford CIFE]. Initially the engineers optimized on the baseline design of the buildings and came up with two scenarios illustrated by marks in figure3.5, representing scenarios with most reduced life-cycle costs and reduced carbon footprint respectively.

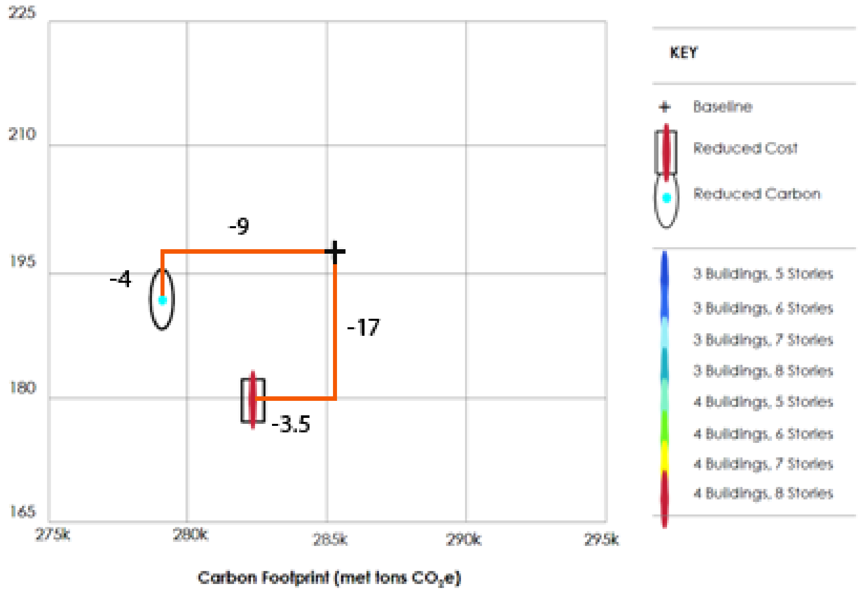


Figure 3.5 - Life-cycle cost vs. carbon footprint of the initial design (baseline), reduced costs (blue) and reduced carbon footprint (red). (Figure: [Stanford CIFE]) (See larger image in appendix D).

In figure3.5 it is seen that the blue mark represents a scenario with reductions of approx. USD 4 million (~2%) and 9,000 tons CO_2 (~3%) in life-cycle costs and carbon footprint respectively. The red mark represents reductions of approx. USD 17 million (~9%) and 3,500 tons CO_2 (~1%) in life-cycle costs and carbon footprint respectively. Both of these (engineered) scenarios optimize the original baseline design, but the design team was not content with results. Instead they used a Cloud Network of computers to run 21.360 alternative design simulations simultaneously with the stated variables and plotted the results on a similar graph as seen in figure 3.6.

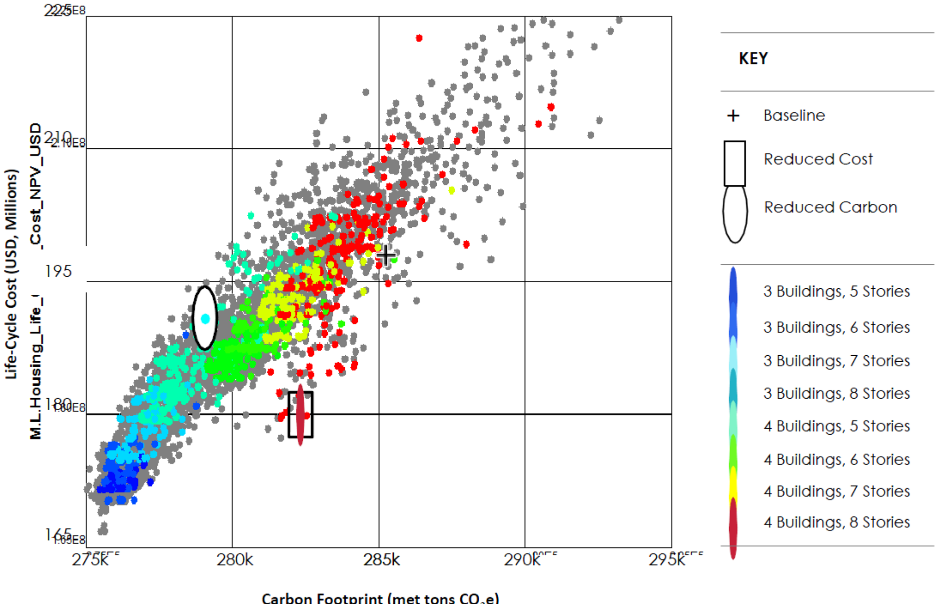


Figure 3.6 - Illustration of the 21.360 alternative scenarios simulated by a Cloud Network together with the baseline design and the two previously optimized scenarios. (Figure: [Stanford CIFE]) (See larger image in appendix D).

Figure 3.6 depict the many outcomes plotted on a life-cycle costs vs. carbon footprint graph and their corresponding number of building and stories all generated through the use of a Cloud Network. The graph illustrate that many of the plotted scenarios are less favorable than the three scenarios from figure 3.5), but there are also quite a few that performs better than the two engineered scenarios. This provided a much larger basis for the design team to make their choices on compared to two engineered scenarios which are much like a traditional design process.

As with much else there are certain constraints and drawbacks to this MDO approach and Cloud Network such as specific knowledge on how to operate many simulations simultaneously as well as access to a large computer network is required. In this case the total design time incl. set up was increased by 20 hours (~12%) compared to performing only few engineered solutions, but the many simulation scenarios resulted in a reduction of 27 million USD and 10,000 tons CO_2 emission [Stanford CIFE].

3.4.3 Discussion

It would seem that in reality it is not a question whether BIM has come to stay, judging from the numerous benefits in all phases of the AEC industry in regard to the entire life-cycle of a building project. This is underpinned by surveys proving that BIM is increasingly being used and stakeholders expressing their satisfaction with this, not to mention legal requirements in Denmark requiring use of BIM in all projects over a certain minimum size in certain building types the future. Rather, the real question is, what details of the complex puzzle of BIM can still be improved upon and how? As described, there are many aspects, requirements, standards etc. to keep track of in each process stage of a BIM workflow for each party in the AEC industry, and it involves use of a large suite of software tools. That is why, if BIM is to be used in a broad sense standardization and development of proper IDMs are necessary in order to ensure a smooth workflow and that the software programs used for BIM can communicate and transfer information unhindered. Furthermore, knowledge regarding the necessary precautions in order to make BIM work has to be available to project partners as well as what can be expected to come out of a transition into BIM. Section 6 in this thesis looks into practical use of this based on a case study by the use of integrated design process in relation to energy and indoor climate simulations in buildings.

Furthermore, model checking software is necessary to check the consistency and interoperability of various discipline models from different project partners in a building process. Again, based on the same case study use of this type of software is investigated with Solibri Model Checker in section 6.

As described BIM and IDM are both rather complex concepts which both involve an abundance of sub-processes. How can we make sure that the AEC industry is not overwhelmed by all the requirements and standards involved with BIM and make the transition toward this as smooth as possible? As mentioned, task groups and research projects are making a tremendous piece of work in this context, not least by giving examples on how to achieve tangible benefits. The author believes that alongside the Client Requirements these examples are the key to providing a breakthrough in the cultural change from the conventional document based workflow toward a model based workflow and spreading it out in a broader sense to the AEC industry. BIM may be the best concept in the world, but without these incentives the transition process until the majority of the AEC industry has partly or completely adopted BIM will be prolonged, because the transition requires investment and proactive actions to change traditions. An important fact to keep in mind is that the focus of using BIM always has to be to provide an increased value to the project and its main goal in the form of a better end result, but also through a better and increasingly integrated overall process in order to reach the main goal.

Regarding the Cloud Network, this is an example of one new way of utilizing the many possibilities of BIM. This approach can potentially aid the design team find the ideal solution for a given task by using many computers simultaneouly with relatively few extra man hours. The autors personal oppinion in this matter is that this approach seems to have destinct advantages as stated in the Standford example, which will be sought for in the future. However, a working approach like this is still quite far from the way in which most practitioners in the AEC industry works today. This is why the author believes that the BIM concept still has some way to go before utelization of a Cloud Network is seen implemented in building projects on a regular basis in Denmark and internationally. This is based the fact that BIM is still not fully developed nor commonly adapted by the building industri yet. Additionally, specific knowedge/experience in this field and a large amount of decicated computer capacity is necessary, not to mention that it is only worth spending the extra time for set-up of simulations in projects above a certain minimum size/price.

On the other hand, if an increased portion of releases payment of the total budget is made at the beginning of a project as suggested in the MacLeamy curve in figure 3.3, the design team would have more time to invest in this kind of approach. This might give practitioners the extra incentive to invest in implimentation of this approach on company level as well as project level. Taking the above considerations into account, the author believes that an MDO approach with a computer simulating Cloud Network will be seen realized in the Danish building industry within the next five-ten years, but it is not a subject investigated further in this thesis.

4 Method

This section concerns a brief description of how the document based workflow and the model based workflow has been approached. Included in this are short descriptions of the different software having been used throughout the thesis, which of the two processes they are part of and how and why they are important in this thesis.

4.1 Choice of programs and processes

The choice of programs used throughout the preparation of the thesis is based on being commonly used programs in the industry and their being available to the author. The programs used as examples in the document based workflow and the model based workflow respectively as well as their order of use are illustrated below. (-->: indicates no model transfer on geometry redrawn and information retyped; →: indicates geometry transfer, possible with information attached).

Document Based Workflow (DBW):

- Energy: AutoCAD -- > Be10 (steady state simulation)
- Indoor environment: AutoCAD --> Bsim (dynamic simulation)
- Indoor environment: AutoCAD --> TCD (steady state one day simulation)
- Daylight: AutoCAD --> SketchUp → Daysim (daylight factor calculation)*
- Exchange test: AutoCAD → IES<VE> (only exchange test, no actual simulations)
- Exchange test: SketchUp → IES<VE> (only exchange test, no actual simulations)**

* The 3D SketchUp model was created based on 2D drawing from AutoCAD and the imported to Daysim.** This process can exchange many of the same information as the Revit → IES<VE> in terms of geometry and predefined building component, but since SketchUp is not a BIM tool and cannot export IFC files it is located in this category.
The latter two test exchanges handles geometry transfer model, but it does not involve a proper BIM information exchange as the next two ones does.

Model Based Workflow:

- Indoor environment, energy and daylight: Revit → IES<VE> (dynamic simulation)
- Consistency and collision control of model: Revit → Solibri Model Checker (common checking method for subject models used for various purposes).

As can be seen in the two lists above the DBW is more cumbersome or has more limitations than the MBW by either involvement of more programs, remodeling or no proper BIM information exchange. Alternative processes such as e.g. Autocad --> IES<VE> could also have been made, but would not involve any kind of model exchanges and is therefore not included.

4.2 Description of the building simulation programs

In table 4.1 is a list of the four building simulation programs used in the thesis, and below this is a description of each of these.

Table 4.1 – Overview of used software during the preparation of the thesis, their respective simulation period and project stage

Software	Representative simulated geometry	Simulated time period	Program used in project stage
Be10:	1 room	1 day	Conceptual & Project Proposal
TCD:	1 room	1 year	Conceptual
Bsim:	1 room	day, week, month, year	Project Proposal
IES<VE>:	5 rooms	day, week, month, year	Project Proposal/ Preliminary Design

4.2.1 Be10

Be10 is a software program developed by the Danish Building Research Institute (Statens Byggeforskningsinstitut (SBi)). The program is used as the mandatory software to perform the required energy frame documentation stated by the Danish building code (BR10).

Be10 uses inputs concerning the building envelope, internal gains, energy used for building operation, and design temperatures of -12 °C and 20 °C outside and inside respectively, to determine a building's heat losses through a steady state calculation. With this information and input about the building's energy source the program determines the amount of energy to be used for building operations per square meter as well as resulting overheating hours and describes the amount of energy related to each part of the building operation.

4.2.2 TCD

The software Thermal Calculation by Design (TCD) is developed in relation to a master thesis made at DTU by Heini Ellingsgaard og Anders Kastberg in 2009. The program is used to calculate solar radiation and mean interior operative temperature over the course of 24 hours in buildings in Denmark on a cloudless day. The program bases it calculations on relatively few input parameters regarding the building envelope, orientation, internal heat gains, infiltration rate and ventilation parameters and uses the calculation method from "Indeklimahåndbogen" [Indeklimabog] as well as solar radiation curves from DANMVAK-bogen [Danvak] [Ellingsgaard & Kastberg]. TCD is an Excel spreadsheet consisting of one input section and six result sections which comprises of the mean interior operative temperature and solar radiation curves for various orientations inputted by the user.
The program bases it calculations on a situation with external mean, min. and max. temperature inputs on a given date, while the user is prompted to input data for the windows and their orientations in order for the program to calculate the solar radiation for that specific room/building.

The mean interior operative temperature is a result of the internal heat gains in the room, the exterior temperature, solar radiation, heat losses through transmissions to exterior and adjacent rooms and ventilation as well as the inlet air temperature in the HVAC system [Ellingsgaard & Kastberg]. TCD calculates the mean interior operative temperature based on the following formula:

$$\bar{t}_i \qquad \frac{\overline{t_u} \cdot B_u + t_l \cdot \frac{B_L}{24} + \overline{t_u} \cdot B_i + \overline{\phi}}{B_u + B_i + \frac{B_u}{24}}$$

t_i	Mean interior operative temperature over the course of 24 hours [°C]
t_u	Exterior mean temperature over the course of 24 hours [°C]
B_u	The thermal conduction between interior surfaces and the exterior, which is used to calculate the transmission losses based on the exterior mean temperature over the course of 24 hours [W/K]
t_l	Inlet temperature of the HVAC system [°C]
B_L	The ventilation air flow capacity used to calculate the ventilation losses from mechanical ventilation and natural ventilation [W/K]
B_i	The ventilation air flow used to calculate the ventilation losses in through infiltration [W/K]
Φ	The average gain from solar radiation and internal heat gains [W]

TCD basis its calculation on what is called true solar time meaning that during summer one hour is to be subtracted from regular time to get the true solar time. This is important when setting up the time dependent solar shading.

4.2.3 Bsim

In brief, Bsim is another tool created by SBi like Be10 and the two are often used in subsequently to one another [Esbensen]. Where Be10 calculates a building's estimated yearly energy consumption, Bsim simulates its indoor climate based on some of the results from Be10. Bsim uses a weather data file specific for the project location in this case Copenhagen, Denmark DRY. The simulated building/ room can be assigned with several thermal zones which can encompass one or more rooms, and later each thermal zone can be evaluated separately. The programs interface consists of two main elements; the project tree which is a list of the entire project from Building level → room level → element level → component level and so forth, by which it is easy to locate and modify single components. The second part of the interface is the program´s visual representation of the project in the form of dots and lines (wireframe view) illustrated in four different views. In this interface the user builds his/her project by geometrically constructing the building in the wireframe view by measuring up from CAD drawing or likewise, then insert attributes such as windows and doors and assign all building parts with the proper building component. When the project is complete, it is ready for analysis in the program´s simulation engine tsbi5. After the simulation has run for the chosen time period the user can choose which projects parameters to evaluate, and often there after go back and modify one or more parameters to improve the results and rerun the simulation.

4.2.4 IES<VE>

Integrated Environmental Solutions has created the dynamic simulation software Virtual Environment – together IES<VE>. The programs consists various integrated building analysis applications, which can be combined in different ways to accommodate the users requirements. In the ModelIT application the user can choose to create his/her own model or import and existing one from another program. The program supports the gbXML, DXF and most importantly IFC formats and allows import of geometry from modeling and drawing programs such as Autodesk Revit, AutoCAD and Google SketchUp which will be elaborated on in the case study sections of the report. The ModelIT application can display a 3D wireframe representation of the model geometry on three levels: 1) building 2) room or 3) surface level in which the user can choose to edit in the model and assign building component material. The main simulation engine of the program is the ApacheSim application in which room templates describing e.g. the internal gains, air exchanges can be created an assigned to the respective rooms. The ApacheSim application may be combined to a number of other applications, out of these the most important in regard to this thesis are:

- ApacheHVAC for set up and control of the HVAC system and components
- RadianceIES for daylight and artificial lighting simulation

The program is mainly a tool to perform dynamic indoor environment simulations which can be used to design control strategies after, but the program also gives results of energy uses divided into categories where after the user can calculate the final energy use. The program is validated to perform dynamic indoor environment simulations by EN ISO 13.791 and heating, cooling and building envelope calculations by ASHRAE 140-2007 [Dethlefsen et al. 2012].

4.2.5 Solibri Model Checker

In brief, Solibri allows the user to import one or more IFC models and test for quality assurance and control against one or more chosen rulesets [Solibri]. This could for instance be testing for collisions between two subject models of the same building, one being e.g. the MEP model with the HVAC network tested for collisions with the load carrying structural system of a certain building. Solibri might also simply be used for locating overlapping/ colliding construction parts in one model and generating material lists for construction. After a collision has been identified and corrected by the respective part, it is crucial for other parties in project to be able to identify what changes have actually been made so other subject models can be streamlined. This is possible with the “model comparison” ruleset where different models have each their color in a visual representation. A report can then be generated with details on the changed properties such as quantities and type into an Excel file [Solibri] (see example in appendix E). When the model(s) of question has run the analysis check against the chosen ruleset the program provides a list of associated problems and their location. The program then categorizes the problems into subjects and subgroups and displays where there are unresolved issues and classifies its severity level into high, moderate or low. For instance collision control revealing a pipe going through an architectural wall will be classified as low or moderate issue, where as a pipe going through a structural wall will be classified as high severity [Solibri]. With this information the user can locate each individual issue in the 3D model display and check whether it is acceptable or has to be sent back to e.g. the architect for correction (see illustrations of this in appendix F). Potential collisions can be associated with an illustration and a short description of the issue, its status and who is responsible of correcting it. This can be presented in the form of an Excel sheet, a slide show with notes, or it may be exported back to the respective partner as a BIM Collaboration Format file (BCF(zip)). A BCF file contains only the information that a user has selected and commented on, such as illustrations and notes of detected issues in the 3D model in Solibri and not the entire model itself. This allows the file size to be just the size of a text file [BCF1]. The receiver can subsequently open the BCF presentation/ report in Revit or another modeling program and go through in his/ her own version of the model and correct wherever necessary and resend the corrected BIM model back into Solibri for further check. The correspondence back and forth between the design team participants becomes part of the model´s history, by which it is possible to track responsibility of certain corrections in doubt situations [BCF1].

The company CAD-Q, who distributes Autodesk products in Scandinavia, has developed a software package including a plug-in for Revit called Naviate (previously CQTools). The name is a contraction of the two words Navigate and Aviate, which symbolizes that the program aids with complex problems solving in building models and thereby helps the user reach new heights [CAD-Q]. This is the program to use when importing a BCF file into Revit to correct the issues found in Solibri. However, the program can be used in a broad field of the building industry including product development, architectural design, construction, electrical, plumbing, contracting, landscape design etc. CAD-Q promotes the programs as being based on a lean strategy meaning it is created to increase the efficiency of processes between e.g. programs they distribute themselves. Besides the coupling between Revit and Solibri, the program has functions to reduce duplications of drawings, quality assurance and data management and automation [CAD-Q].

5 Case study – Document Based Workflow

5.1 Energy consumption in Be10

The energy consumption calculation made by the document based workflow has been carried out in the previously introduced software, Be10. All preconditions and the full energy calculation can be found in appendix G (Be10). The building code for low energy class BR15 buildings stipulates an energy frame of 42 kWh/m^2/year, plus extra in situations where special conditions apply, such as usage hours of non residential buildings above 45 per week [SBi, 213]. Tranehavevej daycare institution has a usage of 50 hours per week and this releases an extra 1.3 kWh/m^2/year and the total energy frame for this building becomes 43.3 kWh/m^2/year . The original Be10 calculation indicated an energy consumption of 42.5 kWh/m^2/year. This consumption is divided as follows in kWh/m^2/year net consumption: room heating: 22, domestic hot water: 7.9, cooling: 0.0 and the transmission through the building envelope excluding windows and doors are 3.2 and the requirement is 5 so this is fulfilled.
The transmission coefficients of the building components are given in a list in section 2.8.1.4.

Ventilation

In the original Be10 calculation the building is assumed to have a mechanical air exchange rate of 2h^{-1} during winter and summer for all rooms, plus an additional expected natural ventilated air exchange rate of 2h^{-1}. To minimize the energy consumption the ventilated air is assumed to have a heat recovery factor of 85%, a SEL factor of 1.3 kJ/m^3.

PV panels

The original Be10 calculation indicated a necessity for 25 m^2 PV panel to be located on the southwest roof on the central part of the building. The installation of PV panels was not initially part of the building program, but due to the relatively large transmission areas of the building envelope causing an exceeding energy demand compared to the BR15 requirements. It might have been possible to eliminate the energy demand exceeding requirements without PV panel, if the building had gone through a fully integrated energy design process from the very beginning. From the very first presentation of sketches Esbensen Consulting Engineers had concerns regarding the floor plan made in only one storey and the architects left few opportunities to improve the building's passive design. However, in a design process with varying interests the most optimal architectural design might not cooperate with the most optimal energy solution, and in this case lack of early involvement and flexibility resulted in 25 m^2 PV panel on the roof. The PV panel has a peak power of 0.14 kW/m^2 and a system efficiency of 0.8 (both values determined by a specialist at Esbensen and not questioned by the author).

5.2 Daylight

5.2.1 Background

The Danish building code states that all permanent working areas must have access to sufficient daylight at the working plane, meaning a daylight factor (DF) of 2% or higher. This calculation has to be performed using the CIE overcast sky conditions at the day of fall equinox on the 21st of September at 12p.m. by which the DFs are calculated on the working level (0.75m above the surface of the floor). BR10 additionally requires that any working room should have a window area corresponding to at least 10% of the internal floor area. The latter rule is fulfilled in all the room types with permanent working areas. The rooms that have been chosen for daylight simulation investigations are one of the common rooms, the kitchen and the office. The most important one of these rooms are the common room in which a number of different designs have been simulated to find a solution that would ensure the best possible daylight conditions within the given overall design. Some of these design scenarios adjusted some of the exterior design features, which was not in the interests of the architects and these proposals have been discarded (but can be seen in appendix H). The following is a brief presentation of the simulation method and some design proposals made to optimize the daylight conditions.

5.2.2 Method

Daylight simulations have been carried out in two different software programs at two different design stages. The first one was in the conceptual design phase where the author performed a number of various design proposals to ensure the best daylight conditions with the given overall design. This procedure started with a simple SketchUp model which was transferred to Daysim where the daylight factors were simulated and later the result file was re-imported into SketchUp for display in the original geometric model. The results were then presented to the architects at a planning meeting and used as basis for further actions (see these in appendix H). The final designs have been simulated in the RadianceIES module of IES<VE> in what would correspond to the project proposal stage with a higher accuracy level than seen in the process designs in appendix H. The result of the final daylight simulations are found underneath a brief description of the design process and limitation of each of the three rooms in figures 5.2 – 5.4. In table 5.1is an overview reflectances and light transmittance (LT) values used in the simulations:

Table 5.1 – Reflectances and light transmittance values used in the simulations.

Building component	Reflectance [%]	LT value [%]	Comments
Roof (internal surfaces)	0.7		White surface
Facades (external surfaces)	0.4		
Walls (internal surfaces)	0.55		Relatively light surface, partially covered by e.g. a bookcase
Floor (internal surfaces)	0.25		Dark gray flooring, linoleum
Facade windows		0.73	
Skylights		0.71	
Surrounding vegetation	0.65		Some light shines through the leaves in the vegetation

5.2.3 Proposals

In the daylight simulation for each room the exterior conditions has been taken into account. In the case of the office this involves a large tree nearby; outside the office there is a wall from the middle section of the building perpendicular to the façade and next to the kitchen façade is a roof cover extending from the main building to a tool shed roughly 6m from the main building. In appendix H are large illustrations of the final results and some process designs. The most important design limitation features and their change in the design process are:

Common room (7.5m * 5.9m: 44m^2; orientation southwest):

- The wooden pergola construction in front of one half of each common room façade. Initially this was only 0.9m deep from the façade, but ended up being 1.4m deep. Simulations were made to illustrate that this would negatively affect the daylight conditions in the room, but the architects went on with the idea to try to eliminate the necessity of external solar shading.
- Skylights located toward the back corner of the room as opposed to the centre, providing a dissimilar daylight distribution. Two proposals were simulated to relocate or split the glass area up and align some of the glazing with the rest of the roof and give light to the less lit corner. However, both proposals were abandoned and it was decided to continue with the original design.

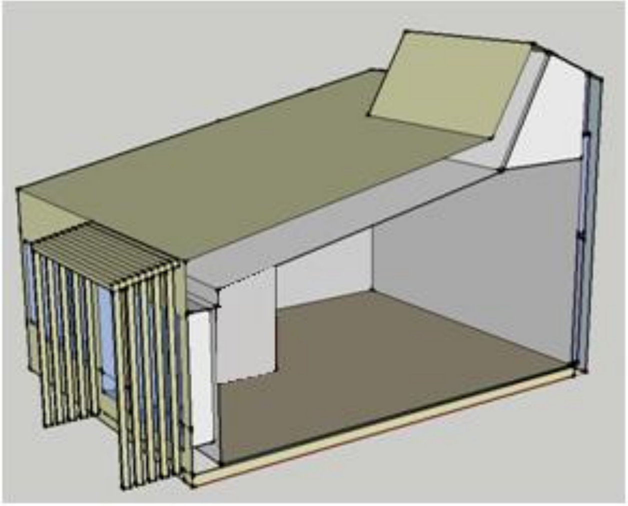


Figure 5.1 – Section cut of the simulated common room. Wooden pergola construction in the front and skylight construction in the back of the room.

Final daylight factors of the common room are illustrated in figure 5.2., it is seen that the daylight factor is unfortunately not 2% in the entire room, but is it a realistic representation under the given circumstances.

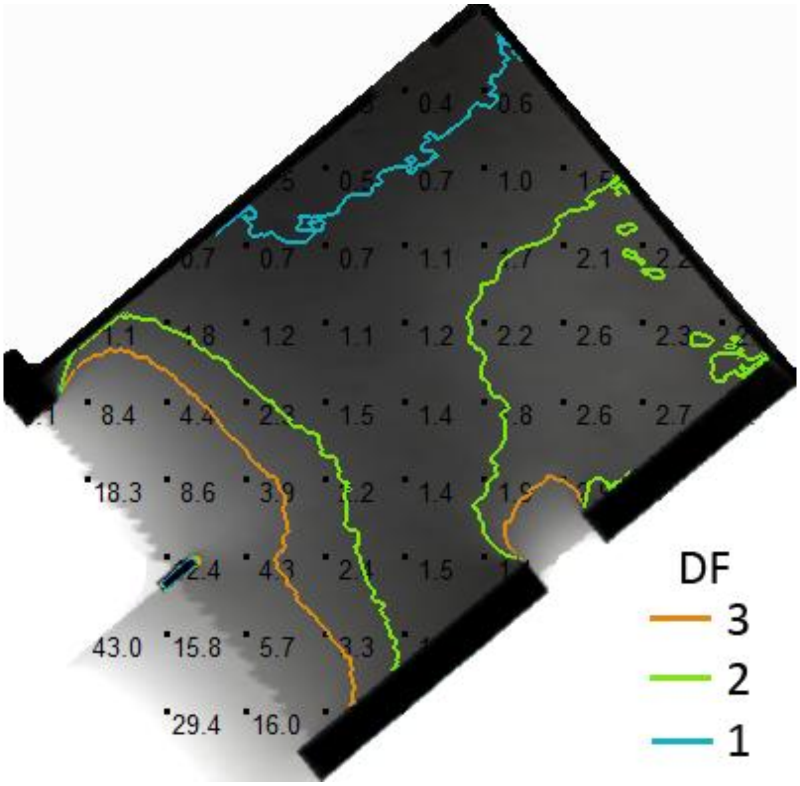


Figure 5.2 - Daylight factors in common room 3 (adjacent to the centre part of the building). The gray area outside the window is caused by the wooden pergola.

Kitchen (8.6m * 5.8m: 50m^2, orientation: southwest):

- The architects insisted on no skylights here, so there is only one window and a glass door in the façade.
- These two glazing areas started out as being approx. ½ of the width of the façade but were increased to approx. ¾ of the width to increase the daylight near the façade.
- Outside the room, toward the southeast is an approx. 1.7m wide pergola construction belonging to the adjacent room.

An illustration of the final daylight distribution in the kitchen is seen in figure 5.3. The figure illustrates that the 2% daylight factor boarder line is only approx. 2.8m into the room from the façade and the rest of the room falls below the minimum requirements of permanent working locations.

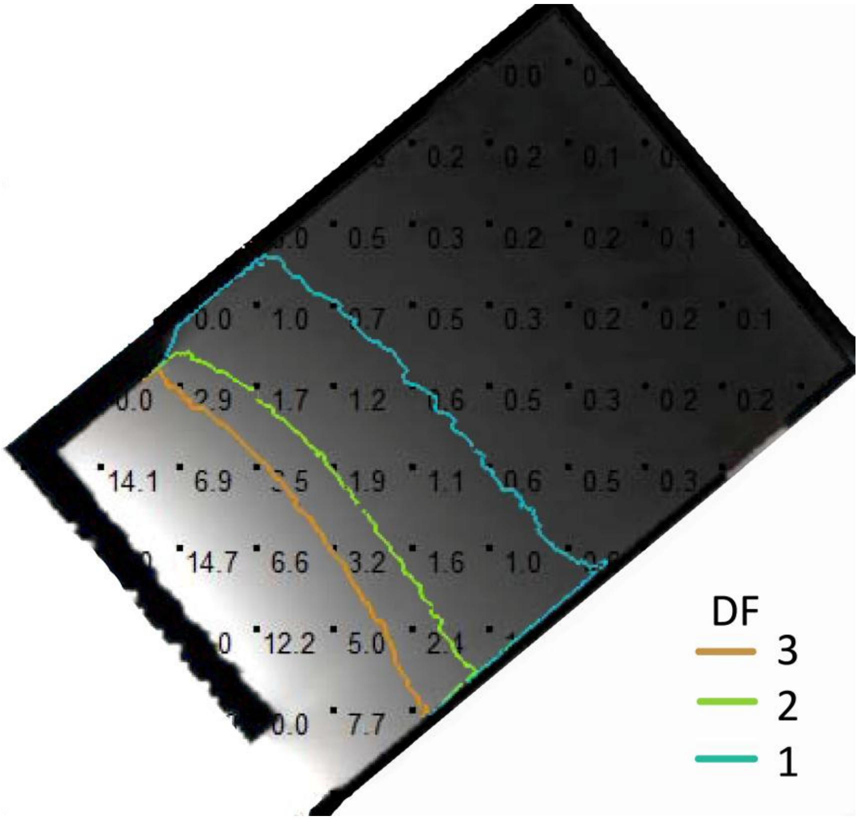


Figure 5.3 - Daylight factors in the kitchen in the middle section of the building. The kitchen is 8.6m deep and the 2% daylight factor boarder is roughly 1/3 (2.8m) of the way into the room from the façade. (The dark marking next to the door is the parapet; the windows are just over this).

Office (4.5m * 2.9m: 13.3m^2, orientation: northeast):

3) Only one large window (1.5m x 1.5m) toward the northeast with an approx. 10 tall tree relatively nearby, which could not be cut down. There were not very many design parameters to change here, so it was decided to include consideration of locating the workspace next to the façade interior design proposal.

An illustration of the final daylight distribution in the office is seen in figure 5.4. The 2% daylight factor boarder line is seen to be approx. 2m from the façade. The main limiting factors for this rooms daylight is the large tree in front of the façade.

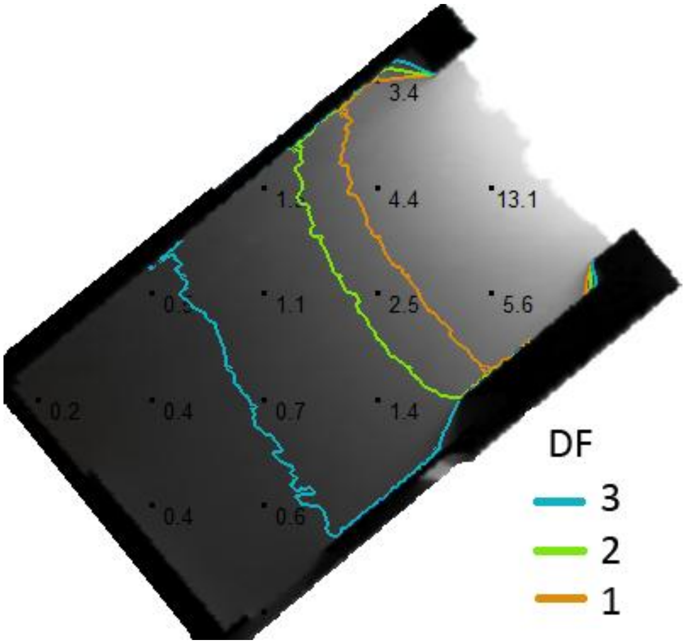


Figure 5.4 - Daylight factors of the office. The boarder line of 2% daylight factor is approx. 2m into the room.

Any design change in any aspect of a project will involve limitations and constraints because this change may affect the work of one or more project partners and the total budget. Therefore any change and related costs must be justified by the benefits this change brings to the project. For instance relocating one square meter of the total skylight glazing area to be in line with the roof and thereby spreading the daylight out further (as proposed), may increase the daylight conditions. However, this relocation will involve extra work for modeling for the architect, possibly extra calculation for the static engineer and extra costs for the entrepreneur and could therefore turn out to be a non preferable solution. The lists of the three rooms above demonstrate that several proposals were brought to the meeting table, but other considerations weighted higher than the daylight conditions. In the end no major modifications could be made to increase the daylight conditions, so the process was more a verification of the conditions than an optimization of them.

5.3 Requirements for comfort ventilation

This section contains hand calculations of the necessary air changes in the representative common room, used for benchmarking for later simulations. There are basically three main requirements that have to be fulfilled for comfort ventilation, which are: 1) the regulatory, 2) atmospheric and 3) thermal indoor climate and the ventilation system are to be dimensioned for the largest one of these.

5.3.1 Regulatory requirements according the Danish Building Code (BR10)

BR10 states that the indoor climate in daycare institutions has to comply with the following: Common rooms in daycare institutions have to be ventilated by a unit that includes supply air as well as extraction and heat recovery. The supply air has be a minimum of 3 l/s/child and a minimum of 5 l/s/adult plus another 0.35 l/s/m^2 floor area. At the same time it has to be ensured that the CO_2 content in the indoor air does not exceed 0.1 % (1000 ppm.) If demand controlled ventilation is used, it is allowed to deviate from the specified air quantities when there is a reduced need. However, the ventilation capacity in the occupied hours shall be no less than 0.35 l/s/m^2 floor area [BR10].

The kindergarten section of the daycare institution (the southwestern half) is to be dimensioned for the highest people load (22 children + 3 adults) compared to the (12 children + 3 adults) [Bygpro. Tran]. Therefore one of the common rooms in the kindergarten section will serve as the calculation example to determine the regulatory minimum requirements.

22 children * 3 l/s + 3 adults * 5 l/s + 0.35 l/s * 44 m^2 = 96.4 l/s

Conversion into m^3/h: 96.4 * ((3600 s/h)/(1000 l/m^3)) = 347 m^3/h

Conversion into air change per hour: Net volume: 144.8 m3, 347 m^3/h / 144.8 m^3 = $\underline{2.4\ h^{-1}}$

5.3.1.1 Atmospheric indoor climate

The atmospheric indoor climate is evaluated based on CO_2 concentration in a given room. CO_2 is sometimes referred to as a “tracer gas” because it can be measured and its concentration increases proportional with an increase of human activity. However, CO_2 itself is not the actual cause of poor indoor air quality, but it indicates when the actual causes of poor indoor air quality increases, which it does as a result of a rise in human emitted bioeffluents, such as odors [Stephen, P.]. The CO_2 concentration limit in good indoor atmosphere is 1000 ppm. according to ASHRAE standard. This means that if the CO_2 concentration in a room is higher than 1‰ the air quality is regarded as being poor and may lead to fatigue and a sense of stuffy air. The atmosphere contains a CO_2 concentration of approx. 350 ppm. which is therefore the lowest achievable value to be obtained through regular ventilations systems.

The atmospheric indoor climate requirements are calculated on the basis of the standard DS/EN 15251. The kindergarten is categorized to be in the following category:

Category II for low polluting building materials. Using the formula (B1): $q_{tot} = n * q_P + A * q_B$, q_{tot} = total ventilation rate of the room [l/s], n = design value for number of persons in the room [-], q_P = ventilation rate for occupancy per person [l/s/person], A = room floor area [m^2], q_B = ventilation rate for emissions from building [l/s/m^2]. With the values from table B.2 in the standard this gives:

$$\text{qtot} = 25\ persons * \frac{4{,}2\frac{l}{s}}{m2} + 144{,}8\ m2 * \frac{0.7\frac{l}{s}}{m2}$$, ([15251] Annex B)

q_{tot} = 206,4 l/s ↔ 743 m^3/h

Converting into air change per hour: 743 m^3/h / 144.8 m^3 = $\underline{5.1\ h^{-1}}$
This result however, only takes the number of persons and the building type (kindergarten) into account and not the distribution of children and adults, which means that the number most likely is a bit overrated. It will be interesting to see the actual air change needed to maintain a CO_2 concentration of no more than 1000 ppm. stipulated in [THV1], in the indoor climate simulations in Bsim and IES<VE>.

5.3.1.2 Thermal indoor climate

Requirements: Maximum: 100 hours > 26°C

Maximum: 25 hours > 27°C

(For conformability reasons it is made sure that the temperature does not drop below 20°C)

Internal loads in one common room (estimations):

Children:	80 W/ child * 22 children	=	1760 W
Adults:	100 W / adult * 3 adults	=	300 W
General lighting:	5 W / m2 * 44 m2	=	220 W
Task lighting:	0.5 W / m2 * 44 m2	=	22 W
Total internal loads:		=	2302 W

On top of this comes external heat gain from the solar radiation incident on the windows of the common room. To estimate this, figure 5.5 shows the solar radiation on a horizontal southwest facing façade, which is used to locate the peek time of day and load on a summer day in July (red line in figure 5.5) with clear sky conditions. In this example only southwest façade windows are taken into consideration and the skylights facing northeast with an inclination of 30° compared to a horizontal plane are disregarded. The reason for this is the example shows the peak conditions and the sun will never shine directly through the southwest facing façade windows and the skylights at the same time.

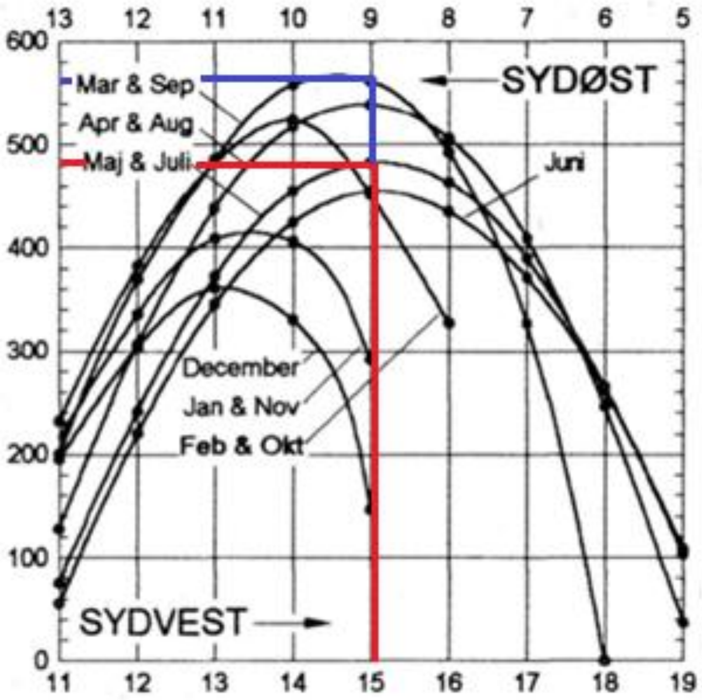


Figure 5.5 - Direct radiant sun through vertical southwest facing non solar shading reference window (traditional double glazed window consisting of 4 mm float glass – 12 mm air gap – 4 mm float glass) [Danvak] Red line: July conditions, Blue line: September conditions.

The formula to calculate the solar radiation on a horizontal surface is:

$$\Phi_{sun} = A * f_a * f_c * (g_{current} / g_{reference}) * (f_{shad} * I_{t,direct} + I_{t,diffuse}) \text{ [W]}$$

Where:

Φ_{sun}: Solar radiation through the window's glass area [W]

A: Gross area of the window [m^2]

fa: Correction factor for the glass area, A_{glass}/A [-]

fc: Shading factor [-]

$g_{current}$: g-value for the current window [-]

$g_{reference}$:g-value for a standard reference double glazed window [-]

f_{shad}: Correction for shadows on the window [-] (no shadows: $f_{shad} = 1,0$)

$I_{t,direct}$: The direct sun energy density transmitted through the non-solar shaded glass area of a standard double glazed window (reference window) [W/m^2]

$I_{t,diffuse}$: The diffuse sun energy density transmitted through the non-solar shaded window glass area of a standard double glazed window (reference window) [W/m^2]

In this estimation the following values has been assumed:

A: 10. 1 m^2 . f_a: 0.83. f_c: 1/0.8/0.2. $g_{current}$: 0.57. $g_{reference}$: 0.76. f_{shad}: 1. $I_{t,direct}$: 480 W/m^2 (from figure 5.5, 3 p.m. on a day in July). $I_{t,diffuse}$: 30 W/m^2 (example).

First the solar radiation on the window with **no solar shading** are calculated:

Φ_{sun} = 10.1 m^2 * 0.83 *1.0 * (0.57 / 0.76) * (1 * 480 W/m^2 + 30 W/m^2)

Φ_{sun} = 3206 W

Then **internal solar shading** with fc = 0.8 on all the window areas toward southwest:

Φ_{sun} = 10.1 m^2 * 0.83 *0.8 * (0.57 / 0.76) * (1 * 480 W/m^2 + 30 W/m^2)

Φ_{sun} = 2565 W

Finally **external solar shading** with fc = 0.2 on all the window areas toward southwest:

Φ_{sun} = 10.1 m^2 * 0.83 *0.2 * (0.57 / 0.76) * (1 * 480 W/m^2 + 30 W/m^2)

Φ_{sun} = 641 W

This example clearly illustrates the effect of internal and external the solar shading system. It illustrates that if a shading system is used as opposed to leaving the thermal indoor climate entirely to the ventilation system, it is possible to save significantly on the energy and thereby also minimize the environmental impact. This will be illustrated further in various scenarios in TCD and Bsim in later sections.

As a comparison, if the solar radiation were calculated on a clear sky day in September (blue line in figure 5.5) when the sun is lower on the horizon but still very powerful, the result with no shading is:

($I_{t,direct}$: 560 W/m^2), Φ_{sun} = 3709 W.

When continuing the example with the solar radiation on a warm July day, no shading plus the internal loads the result is: 3206 W + 2302 W = 5508 W.

The regulatory requirements states that the temperature should not exceed 26°C for more than 100 hours a year, so this is used as maximum and an inlet temperature of 16 °C is used as minimum. So it is now possible to make an estimate of the necessary airflow to maintain the maximum temperature in this example through the following formula:

$$\Phi_{cooling} = \rho * c * q_v * (t_{ext} - t_{int}) \Leftrightarrow qv = \frac{\Phi\text{cooling}}{\rho * c * (\text{text} - \text{tint})}$$

Where: $\Phi_{cooling}$: internal + external loads [W] ρ: density of air: [kg/m^3], c: heat capacity of air [J/(kg*K)], t_{ext}: exterior temperature [°C]. t_{int}: interior temperature [°C].

$$qv = \frac{5508\ \mathrm{W}}{1.2\frac{\mathrm{kg}}{\mathrm{m}^3} * 1006\frac{J}{\left(\frac{kg}{K}\right)} * (26-16)K} \Leftrightarrow q_v = 0.456\ \mathrm{m}^3/\ \mathrm{s} \Rightarrow 1642\ \mathrm{m}^3/\mathrm{h}$$

Conversion into air change per hour: 1642 m^3/h / 144.8 m^3 = <u>11.3 h^{-1}</u>
(Using the situation with the external solar shading which is more likely the result is:
q_v =0.2438 m^3/ s => 877 m^3/h => 6.1 h^{-1}).
Again this is the very highest exposed situation of internal and external load, but it gives an idea of how much the room would have to be ventilated to maintain a maximum temperature of 26 °C.
However, over the course of a regular day the conditions will be much different due to variations in internal as well as external loads. If the ventilation system were to run during the nights of the summer period and thereby cool down the room air and room surfaces before the start of the working day, the situation would be much different as will be illustrated in the dynamic building analysis in later sections.

Summing up on the three different requirements the results are respectively:

Regulatory:	347 m^3/h = 2.4 h^{-1}
Atmospheric:	743 m^3/h = 5.1 h^{-1}
Thermal:	1642 m^3/h = 11.3 h^{-1} (incl. ext. solar shading: 877 m^3/h = 6.1 h^{-1})

So the two first requirements are minimum values for air change in the common room, where as the thermal indoor climate requirement is the maximum value in the peak condition. On a daily basis the actual conditions will be very different due to variations in internal load and solar radiation, but this serves as a dimensioning example of how high internal and external load values may reach. More accurate results will be provided with simulations of the indoor climate in Bsim and IES<VE>. This calculation serves as mere benchmark values for which of the requirements that is going to be the decisive one in the dynamic analysis.

5.4 Building calculations in TCD

5.4.1 Case

In this case TCD has been used as a design tool between the estimations made in section 5.3 and Bsim simulations, but the design freedom was limited from the architects' side, so only alterations on the air change rates and solar shading are possible in order to influence the mean interior operative temperature.

The case study in TCD is based on of the kindergarten common rooms (see figure 2.4) on a warm summer day in July, where it is assumed that 2 of the 3 adults and 15 of the 22 children are present in the room for 8 of the 10 hours the daycare institution is open. This might be a high estimate considering that the occupants can go outside as they please. The people load is assumed to be the standard 125 watts per adult incl. moisture and 65 watts per child incl. moisture which is roughly 50% of an adult. (More accurate calculations will come in more detailed sections later on). The ventilation strategy used is a combination of three different types, which are determined on the basis of the formula for daily mean temperature given [Danvak] on a cloudless summer day in Denmark to be 21°C ± 6°C over the course of 24 hours. The day temperatures are then assumed to be between 21 °C and 27°C which gives an average of 24°C and the night temperature are assumed to be between 15°C and 21°C with an average of 18°C. The three ventilation components consists of mechanical day ventilation at 24°C, same temperature as the natural day ventilation, and lastly the mechanical night ventilation is at 18°C. An important point to state regarding the natural ventilation is that this is completely human operable, i.e. the ventilation can only work in the daycare institution's open hours of the week. In the common room simulated in TCD and in a later section in Bsim, the operable windows and doors are the small façade window, the garden door and the skylights windows. To limit the incoming solar radiation two types of solar shading devices are tested an internal and an external one. These are set to activate at an incidence radiation of 100 W/m^2 and to be time dependent according to its orientation and based on the solar radiation graph in TCD shown in figure 5.6 below. The simulated common room has an adjacent room on one side, the southwest façade has a glass area of 9.96 m^2, the southeast façade has a glass area of 0.8 m^2 and a roof 2.6 m^2 skylights. There is solar shading on the façade windows but none on the skylights which are orientated toward northeast at an angle of 30° and have a 25% lower g-value than the façade windows (see more details in appendix I).

The following three grahps shows the solar radiation in the room with (red) and without (blue) solar shading:

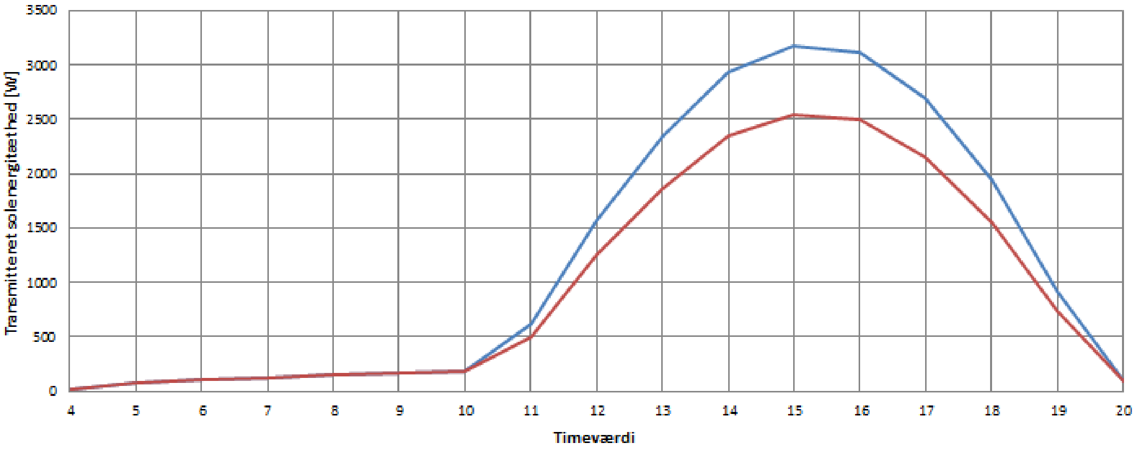


Figure 5.6 - Scenario 1, southwest facade, internal solar shading, factor 0.8. Active between 11 a.m. – 7 p.m. true solar time which is between 12 p.m. – 8 p.m. in regular time. Red: with internal solar shading. Blue: without any solar shading.

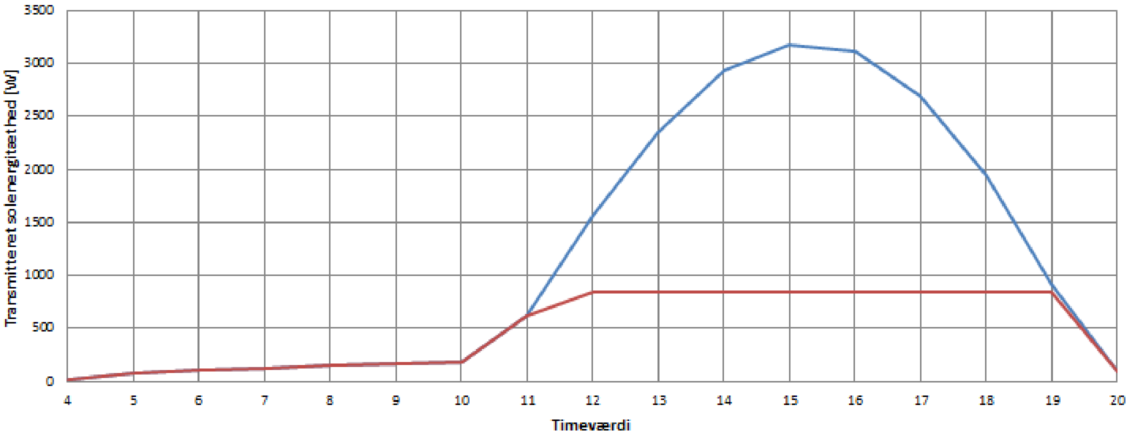


Figure 5.7 - Southwest façade, external solar shading, factor 0.2. Active when the solar contribution reach 100 W/m^2, which is seen is between 12 p.m. – 7 p.m. true solar time which is 1 p.m. – 8 p.m. in regular time. Red: with internal solar shading. Blue: without any solar shading.

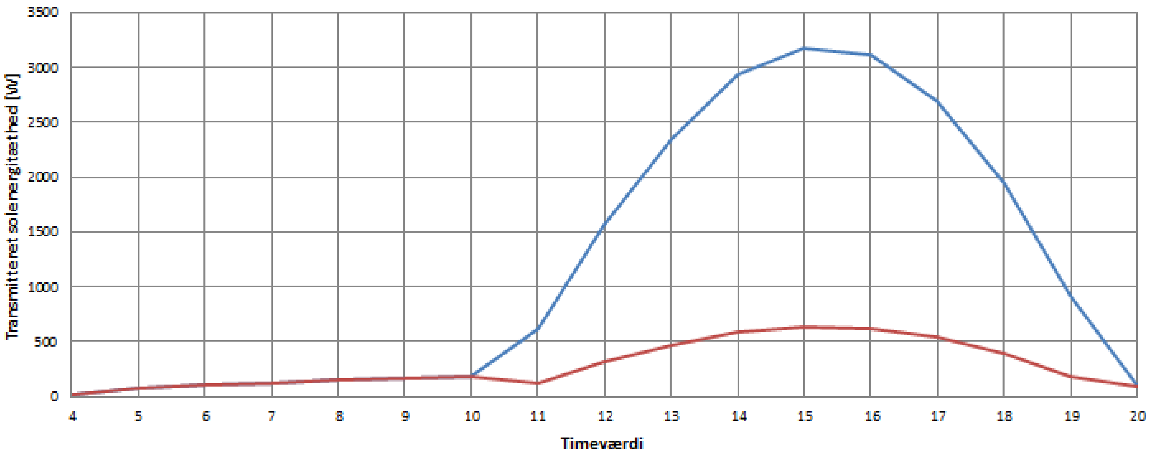


Figure 5.8 - Southwest façade, external solar shading, factor 0.2. Active between 11 a.m. – 7 p.m. true solar time which is between 12 p.m. – 8 p.m. in regular time. Red: with internal solar shading. Blue: without any solar shading.

In figure 5.8 time depending external solar shading it is seen on the blue curve at what time the solar radiation is incident on the southwest façade and therefore why the solar shading is activate in that specified interval when the incident radiation reaches values above 100 W/m^2. This method is used on the southwest façade to specify its corresponding solar shading operative time interval.

According to [Danvak], in a heavy building with external solar shading and moderate internal heat gains, temperature requirements in BR10 of maximum 100 hours above 26 °C and maximum 25 hours above 27°C per year, should be satisfied if the daily mean temperature is below 23°C. In this case the building is not a heavy building, although the ground slap and the internal walls are concrete, the exterior walls and the roof are light weight and well insulated. However, the 23°C will still be used as a requirement guideline for the maximum allowable daily mean temperature in the simulated common room for internal and external solar shading, even though it is expected that internal solar shading is not sufficient to meet the requirement. To make sure that the occurring overheating hours, does not exceed the requirement values, the room will have to be checked more thoroughly in more detailed simulation program such as Bsim and IES<VE> in later sections.

5.4.2 Scenarios

All together seven different scenarios has been investigated on the basis of the results from section 5.3 to get an indication of the best sunscreen solution and ventilation strategy to reach a mean daily temperature below 23 °C.

Common conditions in scenarios:
Internal solar shading factor (sf): 0.8. (In scenario 3 a sf value of 0.7 is tested).
External solar shading factor(sf): 0.2.
Max solar contribution for solar shading to activate: 100 W/m^2
Day open hours from 7 a.m.–5 p.m. (10 hours), night hours is set to 5 p.m.–7 a.m. (14 hours).

Natural ventilation is only available during open hours from 7 a.m.–5 p.m.
The solar shading is automatic and in all scenarios the solar shading is active on the south façade between 6 a.m. – 1 p.m. (based on the solar curve for that orientation) and on the southwest façade the solar shading is active between 11 a.m.–7 p.m. except for scenario 7 which is stated later.
Keep following determinations in mind, which are momentary values from DS/EN15251 indoor category II:

- Atmospheric indoor climate air change rate: **5.1** h^{-1}*
- Thermal indoor climate air change rate: **11.3** h^{-1} *(ext. sun shading: **6.1** h^{-1})*

*All air change rates are incl. natural ventilation determined in [THV1] to be **2** h^{-1}.

The seven scenarios listed below display results of mean indoor operable temperatures over the course of 24 hours:
(The ventilation are written as follows: mechanical vent./ natural vent. (daytime)/ night vent.)
Comparison of the seven scenarios are found in figure 5.10.

Table 5.2 – Overview of the seven scenarios.

	Internal solar shading: sf = 0.8	External solar shading: sf = 0.2	Daytime ventilation rate [h-1]	Natural ventilation rate [h-1]	Night ventilation rate [h-1]	Cooling day/night [°C]
SC1	x	-	3	2	3	-
SC2	x	-	9	2	9	-
SC3 #	x (sf:0.7)	-	9	2	9	-
SC4	-	x	3	2	3	-
SC5	-	x	3	2	5.6	-
SC6	-	x	3	2	4	/16*
SC7 ##	-	x	3	2	4.2	/16*

 # same as SC2 but sf:0.7

same as SC6 but the external sunscreen active from 12 p.m. - 6 p.m. true solar time. (See figure 5.9)

** 14 hours night cooling; ** 10 hours day cooling*

Figure 5.9 below illustrate the sun curve with the solar shading activated according to scenario 7. It is seen that more solar radiation is incident in the room compared to figure 5.7.

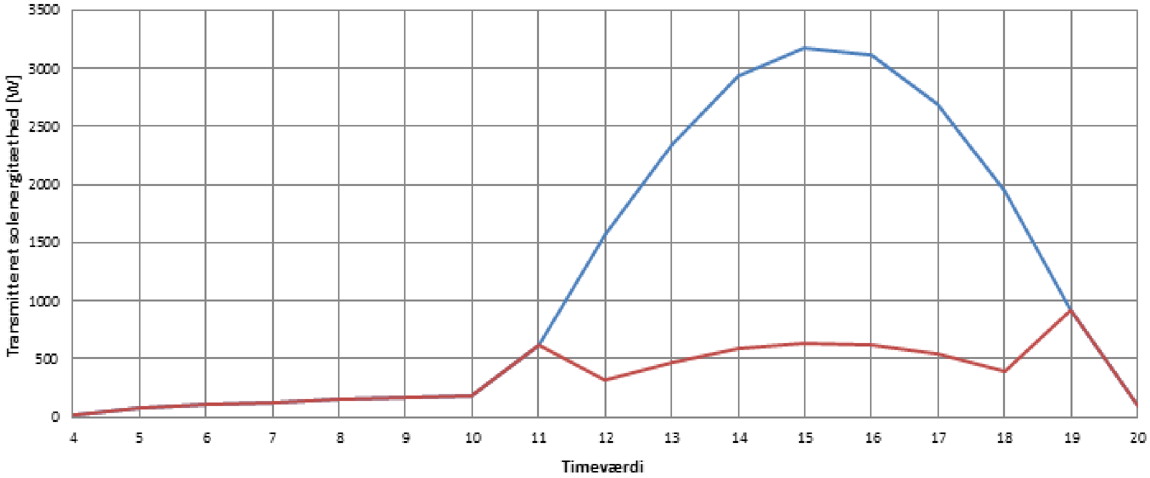


Figure 5.9: Scenario 7, solar shading active from 12 p.m. – 6 p.m. true solar time, 1 p.m. – 7 p.m.

5.4.3 Results

Table 5.3 – Scenario 1 – sf: 0.8, ventilation: 3/ 2/ 3 [h^{-1}] (no cooling), (almost same as the atmospheric indoor requirement).

Mean temperature over 24 hours period	°C
No solar shading:	27.6
Inc. time-dependent solar shading int.:	26.8

As expected this scenario does not satisfy the requirement.

Table 5.4 – Scenario 2 – sf: 0.8, ventilation: 9/ 2/ 9 [h^{-1}] (no cooling), (almost same as the thermal indoor requirement peak value).

Mean temperature over 24 hours period	°C
No solar shading:	23.6
Inc. time-dependent solar shading int.:	23.2

Even with the mechanical ventilation rate increased by a factor 3 to comply with the thermal indoor requirements, this is still not enough to reach a daily mean interior temperature below 23°C. Therefore the next scenario is with a more effective interior solar shading factor.

Table 5.5 – Scenario 3 – sf: 0.7, ventilation: 9/ 2/ 9 [h^{-1}] (no cooling), (almost same as the thermal indoor requirement peak value).

Mean temperature over 24 hours period	°C
No solar shading:	23.6
Inc. time-dependent solar shading int.:	23.1

In table 5.5 it is seen that the improved interior solar shading factor is still not enough to keep the mean interior operative temperature below 23°C. External solar shading is tested next.

Table 5.6 – Scenario 4 – sf: 0.2, ventilation: 3/ 2/ 3 [h^{-1}] (no cooling), (almost same as the atmospheric indoor requirement).

Mean temperature over 24 hours period	°C
No solar shading:	27.6
Inc. time-dependent solar shading ext.:	24.5

The external solar shading lowered the mean daily temperature by 2.3°C compared to scenario 1, but the requirement is still not met.

Table 5.7 – Scenario 5 – sf: 0.2, ventilation: 3/ 2/ 5.6 [h^{-1}] (no cooling), (almost same as the atmospheric indoor requirement and increased night ventilation).

Mean temperature over 24 hours period	°C
No solar shading:	25.2
Inc. time-dependent solar shading ext.:	22.9

Table 5.7 illustrate that to fulfill the requirement below 23 °C without cooling, a mechanical ventilation rate of 5.6 h^{-1} at night is necessary if the daytime ventilation rate is maintained. However, this requires a much larger ventilation system, so adding cooling to the inlet air is tested in the following.

Table 5.8 – Scenario 6 – sf: 0.2, ventilation: 3/ 2/ 4 [h^{-1}] (14 hours night cooling at 16°C).

Mean temperature over 24 hours period	°C
No solar shading:	25.6
Inc. time-dependent solar shading ext.:	22.9

Table 5.8 illustrate the necessary ventilation rate at night if the inlet air at this time is cooled to 16°C and the average daytime ventilation temperature remains at 24°C.

Table 5.9 – Scenario 7 – sf:0.2 active from 12 a.m. – 6 p.m. instead of 11 a.m. – 7 p.m. as the other scenarios. Ventilation: 3/ 2/ 4.2 [h^{-1}] (14 hours night cooling at 16 °C).

Mean temperature over 24 hours period	°C
No solar shading:	25.4
Inc. time-dependent solar shading ext.:	22.9

Table 5.9 illustrate that if the external solar shading is activated from 12 p. m. – 6 p.m. and thereby one hour less in each end (two in total) of the activation period of the day, the ventilation rate has to be increased by 0.2h^{-1}. This is not very much, but keep in mind that the solar shading only affects the occupants one of the two hours because the other hour is at the end of the activation period where the occupants are not present.

Figure 5.10 below illustrates a comparison between the results of mean interior operative temperature in the seven TCD scenarios.

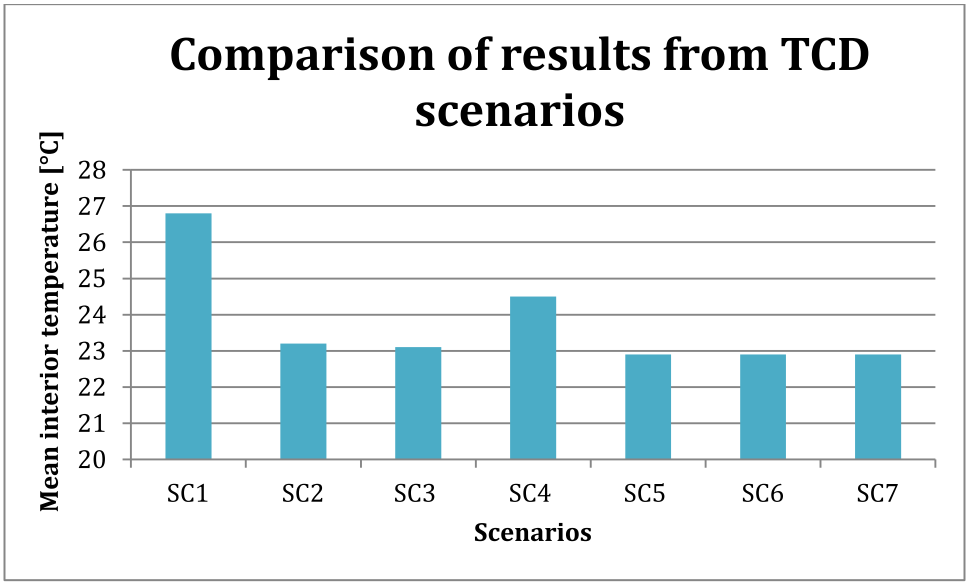


Figure 5.10 - Comparison of mean interior operative temperature results from TDC scenarios. Keep in mind that the goal was to reach a value just below 23 °C.

All together the seven scenarios above demonstrate that external solar shading is necessary in combination with either a relatively high ventilation rate (5.6h^{-1} during night) or night cooling. It is hard to decide, based on the above results, which of scenario 5, 6 or 7 is the best solution when considering energy consumption for cooling versus a larger air handling unit; this will have to be determined in a more detailed dynamic simulations. However, it seems that night cooling might be a good solution and this information will be used later on.

Figure 5.11 illustrate the various air change rates from legal requirements and TCD scenarios compared to each other to illustrate these more clearly. In figure 5.11, the terms VAV is used in the sense that the ventilation is changeable from day to night with given operation periods. However, it is not VAV in the sense that there is no room sensor which can adjust the flow rate in the middle of these operation periods, which means that the flow rate is effectively constant during the entire day and the entire night.

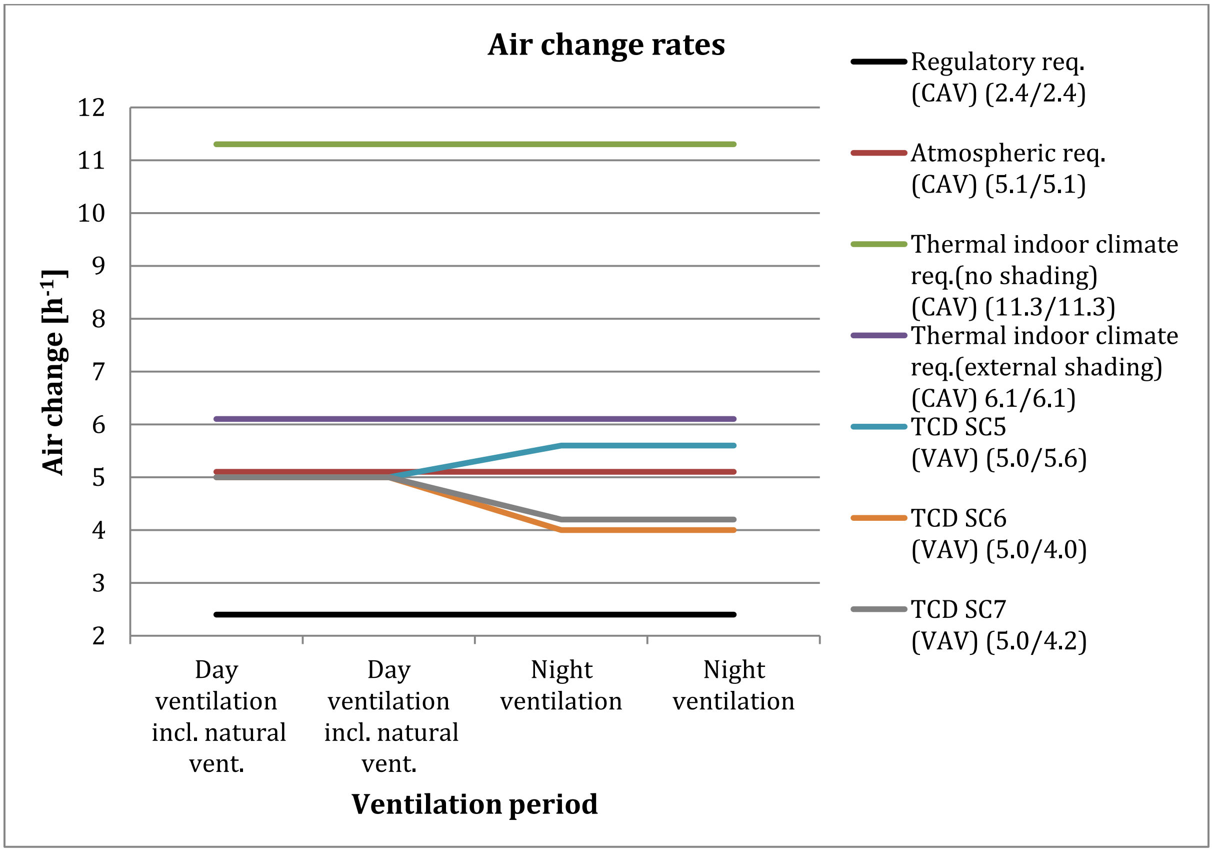


Figure 5.11 - Comparison of required air change rates from BR10 and TCD scenarios 5, 6 & 7 (taken on a warm 24 hours period). (Day ventilation rate incl. natural ventilation/ night ventilation rate [h^{-1}]).

It is seen in figure5.11, that all air change rates from TCD are roughly the same as the atmospheric requirement at day (5.0 compared to 5.1 respectively). At night scenario 5 (no cooling) increases ventilation rate. Scenario 6 (nigh cooling at 16 °C) decrease the total ventilation rate but increase the mechanical ventilation rate from 3h^{-1} – 4h^{-1}, much like scenario 7 which increases ventilation rate to 4.2h^{-1} because the external solar screen is activated one hour less in each end of the activation period.

5.4.4 Sum-up

The few input parameters and instant calculation time makes TCD smart to use at the very beginning of a building design process, by providing mean indoor temperature values it can be used to provide indications on which way to go in relation to window properties and building envelope parameters, if indeed proper design freedom is available to the engineer. However, it should be stressed that TCD is not meant as, nor is it thorough enough to be used as the only calculation tool, but merely as an indicative design aid at early stages. Furthermore, because TCD only offers results in mean interior operative temperatures over the course of 24 hours and no indication of interval size by which this mean daily temperature is taken from, nor number of overheating hours, this software is not sufficient as basis for ventilation dimensioning.

5.5 Building simulations in Bsim

As part of the document based approach the software tool Bsim is used to perform indoor climate analysis on the daycare institution case study. The indoor climate calculation in Bsim has taken place as part of the project proposal stage after the energy calculations in Be10 made in the conceptual design stage. This means that some of the inputs have been reused and others like e.g. the inlet air changes of the ventilation system are detailed much more at this stage because of this program´s dynamic and much more detailed simulation.

This section gives a run through of the model used for simulating the indoor climate for the case study. Three alternative scenarios are made and meant to be presented for the architects, for them to use as basis for detailed design of the common rooms as well as an evaluation of Bsim software.

5.5.1 Technical specifications of the model

Bsim version 6. 10. 7. 5 has been used for this thesis. As representative for the building's most critical room (Common room 1), in terms of thermal indoor climate, has been chosen for the analysis. Figure 5.12 depicts the location of the simulated common room in the southwest corner of the building. This room is chosen due to its exposed position in regard to solar radiation, no shading objects outside the room aside from the pergola, and relative high indoor heat load from occupants.

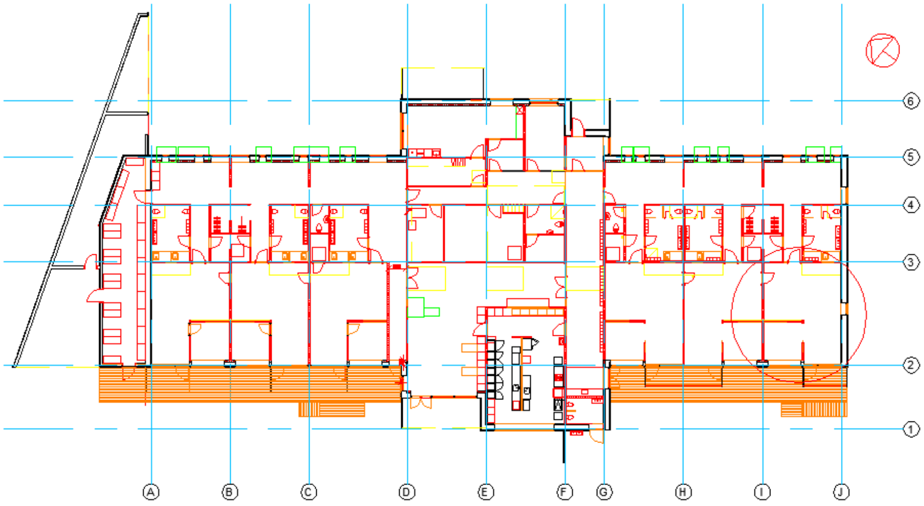


Figure 5.12 - Planview of the daycare institution. The analyzed common room is incircled by red in the lower right corner.

The Bsim model consists of one thermal zone where the quiet zone and the large room are modeled as one. All building surfaces face the outside except the two adjacent to the other rooms which are set to face similar conditions as in the modeled room. The simulated room is 5.9 m * 7.5 m (width * depth) ~ 44 m^2 in floor plan and has a volume of approx. 144.8 m^3. Due to limitations of the simulations software the concave room has been simplified around the skylights which can be seen in figure 5.13.

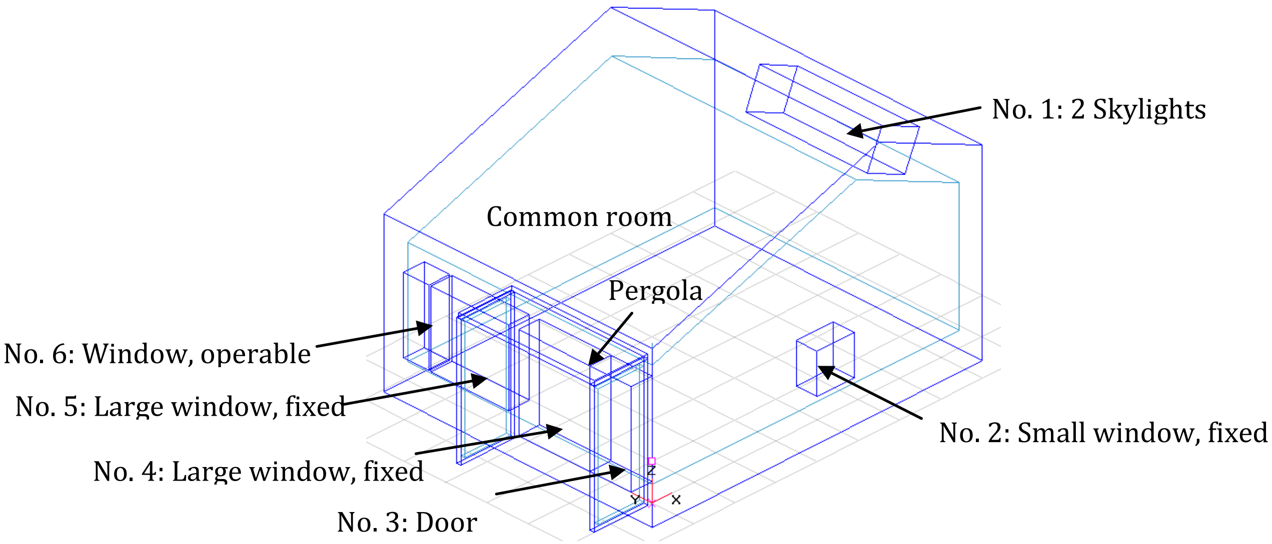


Figure 5.13 Illustration of the analyzed common room 1 in the Bsim wireframe interface.

The transmission coefficients of the building components and glass properties are seen in table 5.10.

Table 5.10 - Building components transmission coefficients and window properties.

Building envelope	U-value total [W/(m^2*K)]	U-value center [W/(m2*K)]	g-value [-]	LT [-]	Gross area/ glass area [m^2]
Roof:	0.1	-	-	-	52.5/-
Facade:	0.1	-	-	-	49/-
Windows:	0.95	0.9	0.57	0.73	10.8/9
Skylights:	1.2	1.1	0.43	0.71	2.7/2.2
Ground slab:	0.1	-	-	-	52/-

(See details on the windows in appendix C).

5.5.1.1 Internal heat load

Lighting: General: 0.22 kW (5 W/m^2), task: 0.022 kW (0.5 W/m^2)

Occupant load:
Standard people load: 125 W/person (25 W/person is moisture).
Initial assumption by Esbensen: 140 W/person for children in a daycare institution, based on an assumption of a very high activity level.
An estimate calculation has been made to check a more accurate people load in the daycare institution in the following:

In peak situations, there are 25 people in total in the common room, hereof 3 adults and 22 children. The adults are estimated to have an activity level for sedentary activity of 1.2 met and clothing of roughly 1 clo this results in a metabolic rate of 70 W/m^2 [Indoor climate 11222]. The activity level of the children is estimated to be a bit higher, between light and medium corresponding to 1.6 met and 93 W/m^2 at light level and 2.0 met and 116 W/m^2 at medium level [Indoor climate 11222], both of them with an assumed clo value of 1. Assuming that the 25% of the children has a medium activity level and the rest is light the resulting average metabolic rate is 99 W/m^2. This is then multiplied with the Body Surface Area (BSA) which is given through the following equation [Wiki]:

BSA: $0.007184 * W^{0.425} * H^{0.725}$, W: weight in kg, H: height in cm.

Assumptions: adults: 70 kg, 170 cm
Children (5 years on average): 17 kg, 105 cm [sundhedsguiden] (se appendix J).

BSA, adult: $0.007184 * 70^{0.425} * 170^{0.725} = 1.8$
BSA, child: $0.007184 * 17^{0.425} * 105^{0.725} = 0.70$

Heat production:

Adults: 70 W/m^2 *1.8 m^2 ~ 127 W/person
Children: 99 W/m^2 *0.7 m^2 ~ 69 W/person
Total: 127 W *3 adults + 69 W * 22 children =1899 W ~ 1,9 kW
(at peak situations, estimated user pattern are shown below).

Compared to the standard input (125 W/person) and Esbensen initial input (125 W/adult and 140 W/child) this average input value of 76 W/person (adults and children combined), seems to be more realistic when considering that most of the occupants are children with a body size half of an adult.
Moist production is assumed to be: 1.5 kg/h (0.06 l/h per person); CO_2 generation: 323 l/h (educated guess on the basis of Bsim standard input).

5.5.1.2 Occupant user pattern

Table 5.11 - User pattern, September – April.

Hour	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm
Load	10%	25%	80%	100%	100%	100%	100%	100%	100%	50%

Table 5.12 - User pattern, May – August.

Hour	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm
Load	10%	25%	50%	50%	100%	25%	25%	25%	25%	25%

5.5.1.3 Ventilation

The ventilation strategy has been determined in combination with two different sunscreen solutions to ensure a comfortable indoor environment according to BR10 and at the same time minimize the energy consumption. All ventilation strategies in the scenarios are VAV controlled. The three scenarios are very simply divided into:

1) External shading + no cooling
2) External shading + 0.5 kW cooling
3) Internal shading + 1.0 kW cooling (see more details in table 5.16 – 5.18 below)

After this each scenario has been optimized to minimize its ventilation rate and cooling load and therefore its energy consumption.

Table 5.13- Common ventilation settings for all 3 scenarios (values are used unless otherwise stated).

VAV settings	All scenarios
Min inlet temp. [°C]	18
Max inlet temp. [°C]	23
Setp. Indoor air [°C]	22
Full load [°C]	24
Setp. CO_2 [ppm.]	900
Air hum.[kg/kg]	0.07
Infiltration [h-1]	0.06

Table 5.14 - Natural ventilation.

Natural ventilation	Summer weekdays: Jun.-Aug. Mon.-Fri. 7 a.m.-5 p.m. setp.: 20°C	Open hours rest of year: Jan.-May + Sep.-Dec. Mon.-Fri. 7 a.m.-5 p.m. setp.:24 C	Sept. CO2 concentration [ppm.]
All scenarios	Up to 2*	Up to 2*	900

**The natural ventilation rate of up to 2 h^{-1} is determined in [THV1] to be required by the client.*

5.5.1.4 Heating

The institution is heated through a radiant heating floor system, which is active in the period from the middle of September until end of April. The supply temperature in the system is dependent on the exterior temperature so when the exterior temperature increase the supply temperature in the system decreases in order to maintain operative temperatures as seen in table 5.15.

Table 5.15 - Operation control of the radiant floor heating system.

Heating (Sep.-Apr.)	Pursued operative temperature [°C]	Maximum surface temp. at outdoor design temp. [-12°C]
Occupied (7a.m.-5p.m.)	22	30
Unoccupied (5p.m.-7a.m.) + plus weekend	19	30

These scenarios above are worked out by taking advantage of the results obtained in the section 5.3 (Requirements for comfort ventilation) and the results from section 5.4 (TCD). After this, it was chosen to investigate three of the most relevant solutions seen from a combined architectural and energy point of view. Design wise the preferred solution would be with internal shading and energy wise it would be best with no cooling. Therefore these two were parameters were incorporated into each their scenario together with a scenario that has both external shading and cooling coil available. The latter one ended up being the only scenario to fulfill the thermal indoor requirements. Results of all three scenarios are illustrated in table 5.19 (below).

5.5.2 Three Scenarios

Table 5.16 - Brief overview of scenarios.

	Mechanical external solar shading (shading factor: 0.2)	Occupant operable internal blinds (shading factor: 0.8)	Max ventilation VAV [h-1]	Max Cooling load [kW]
Scenario 1	X		6	
Scenario 2	X		3	-0.5
Scenario 3		X	3	-1.0

Table 5.17 – Mechanical ventilation (VAV).

Basic vent [h-1]	Summer night Jun. - Aug. Mon. - Fri. 5 p.m. - 7 a.m. [h-1]	Open hours all year Jan.- Dec. Mon. - Fri. 7 a.m. - 5 p.m.	Always [h-1]
			6
1	3	3	
1	3	3	

5.5.2.1 Cooling

In situations where the natural and mechanical ventilation cannot maintain acceptable interior temperatures the cooling coil is activated to add cooling to the inlet air according to the specification given in table 5.18.

Table 5.18 - Mechanical cooling

	Summer nights Jun. - Aug. Mon. - Fri. 5 p.m. - 7 a.m. setp.: 22°C, full load: 24°C	Summer weekdays Jun. - Aug. Mon. - Fri. 7 a.m. - 5 p.m. setp.: 24°C, full load: 26°C	Max cooling load [kW]	Max cooling load [W/m^2]
Scenario 1				
Scenario 2	X*	X	-0.5	-11.3
Scenario 3	X*	X	-1.0	-22.6

**In reality the cooling here will in most cases be regular ventilation because the source (exterior air) will be relatively cool during the night anyway.*

(These scenarios are outtakes/ examples of strategies and could be altered in many ways, but the focus has been on bringing the air change and cooling requirements to a minimum for the sake of minimizing the energy consumption).

5.5.3 Results

5.5.3.1 Thermal indoor climate

Table 5.19 - Results of overheating hours and energy consumption in scenarios for a full year on weekdays between 7a.m.-5p.m.

	Temperature	[hours]	Energy ventilation [kW]	Energy cooling [kW]	Ventilation and cooling combined [kW]	Ventilation and cooling combined [W/m^2]	Relative increase compared to SC2 [%]
Scenario 1	> 26 °C:	76	1725	0	1725	39.3	240
	> 27 °C:	48					
Scenario 2	> 26 °C:	**71**	587	133	**719**	**16.3**	**100**
	> 27 °C:	**25**					
Scenario 3	> 26 °C:	81	676	139	815	18.5	113
	> 27 °C:	36					

No scenarios has any operative temperatures below 20 °C in the open hours of the year.(The energy numbers in table 5.19 shold be considered mostly indicative as a relation between the scenarios and does not necessary indicate the actual energy consumption because Bsim is not used for this, but primarely for indoor climate simulations).

Table 5.19 shows the results of the three described scenarios (see monthly simulations in appendix K). Neither scenario 1 nor 3 satisfies the thermal requirements in BR10 for number of overheating hours above 27 °C. Scenario 2 complies with the thermal requirements and when comparing the three scenarios' estimated energy consumption for ventilation and cooling, scenario 2 also comes out as the preferred choice to continue working with.

The above results are from simulation on a whole year, however in figure 5.14 and5.15 (below) the focus is on one particular summer week with several consecutive days with high internal temperatures as a result of high external temperatures and high solar radiation. In this context the best scenario from above (scenario 2), is compared to “scenario 2 alternative”. These are similar except for their ventilation/ cooling set points (see table 5.20) and available cooling load. Scenario 2 alternative has increased cooling load of -30.0 W/m^2 (compared to -11.3 W/m^2 from scenario 2) to eliminate overheating hours completely.

Table 5.20 – Scenario 2 alternative ventilation strategy

Week 28 only (2. week of July)	Summer nights mechanical ventilation cooling setp. 5 p.m. - 7 p.m.	Summer weekdays mechanical ventilation cooling setp. 7 a.m. - 5 p.m.	Mechanical ventilation rate [h^{-1}]	Natural ventilation rate [h^{-1}]
Scenario 2 alternative	Start at: 22°C full load: 24°C	Start at: 20°C full load: 24°C	3	0

There is no natural ventilation in this scenario because that would spoil the cooling effect.

Scenario 2 alternative is only made for the purpose of illustrating how much cooling will have to be applied to the room to completely eliminate all overheating hours, with otherwise unchanged conditions. This scenario, however, is not realistic to continue working with for three main reasons:

- It is not preferable in terms of energy.
- It is much more realistic that the occupants will open the door and windows if the indoor temperature becomes too high, than to use cooling to solve the problem.
- If the indoor temperature is too high, the occupants are free to move outside unlike an office for instance.

In the two figures 5.14 and 5.15 below the relevant temperatures, air change rates, cooling loads and solar radiation are shown all together for scenario 2 and 2 alternative to get an overview of how these interact with one another and what are the results of the two scenarios different ventilation strategies. Figure5.14 and 5.15 (below) illustrate a full working week, meaning 24 hours of each working day, where only the middle part of each day is the actual open hours (7a.m.-5p.m.) of the institution.

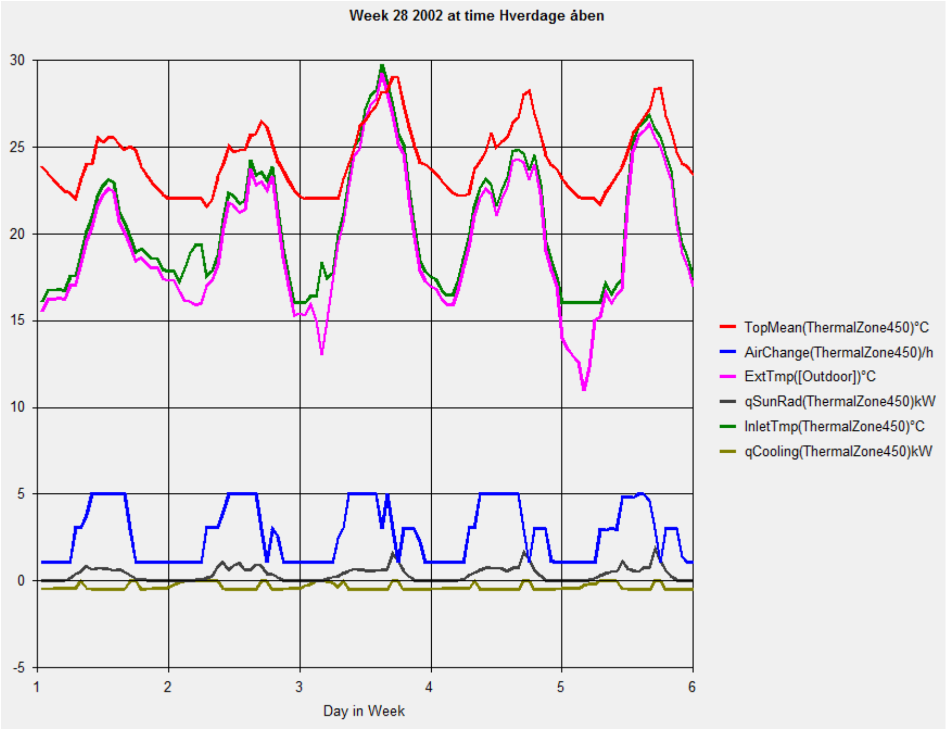


Figure 5.14 – Scenario 2, week 28 (8th – 12th of July), open hours: Overheating hours: > 26°C: 11 hours; > 27°C: 4 hours in this week. (TopMean: temperature operative mean).

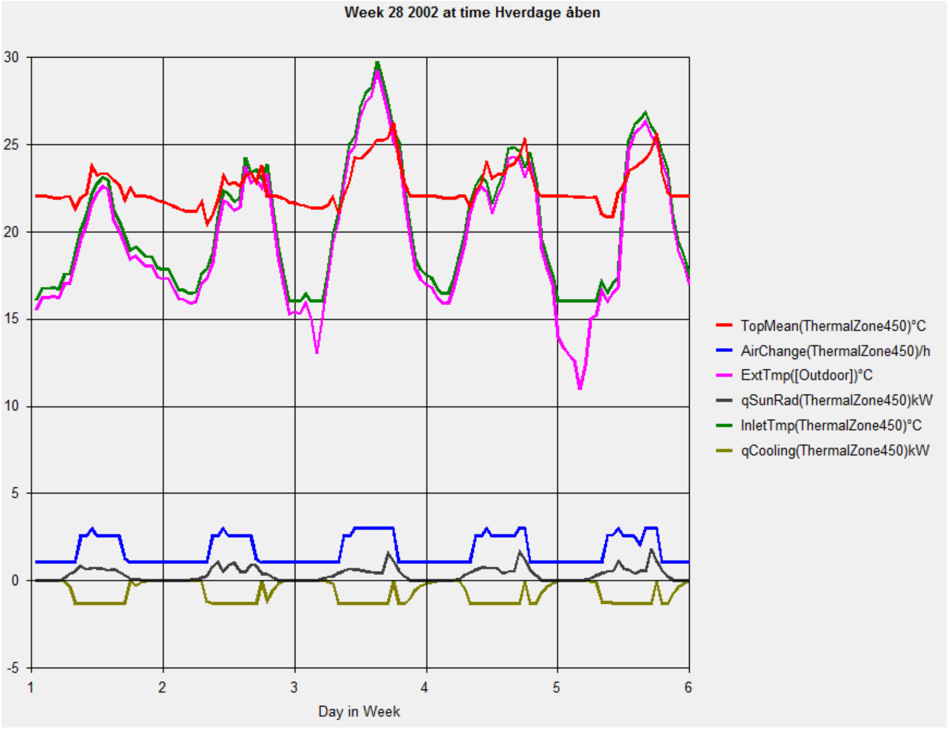


Figure 5.15 – Scenario 2 alternative, week 28 (8th – 12th of July), open hours: Overheating hours: > 26°C: 0 hours; > 27°C: 0 hours in this week.

From the two figures 5.14 and 5.15 above it is seen that the operative temperatures are gennerally lower in scenario 2 alternative than in scenario 2. In scenario 2 there 11 hours > 26°C and 4 hours > 27°C, where as in scenario 2 alternative these overheating hours are eliminated. However, the two figures also shows that because there is no natural ventilation available in scenario 2 alternative the cooling system has to be increased accordingly to keep the temperatures below the limit of 26°C.

Comparison of operative temperatures and the corresponding energy consumption the two scenarios in week 28 is illustrated in table 5.21 (below).

Table 5.21 – Results of week 28 (2nd week in July, Monday – Friday)

Week 28 only	Temperature	[hours]	Ventilation and cooling combined [kW]	Ventilation and cooling combined [W/m^2]	Relative increase [%]
Scenario 2	> 26 °C:	11	29	0.7	100
	> 27 °C:	4			
Scenario 2 alternative	> 26 °C:	0	61	1.4	206
	> 27 °C:	0			

Table 5.21 displays the results of week 28, where it is evident that scenairo 2 is the best result when taking the energy consumption into account. The necessary cooling load to eliminate all overheating hours causes an increase in the ventilation and cooling energy combined of over 100%. Once again it should be remenbered that occupants are free to move out when it is too warm indoors.

The architects originally preferred a design without external solar shading, because that would obstruct the pureness in the design and enhance the important lines perpendicular to the length of the building (see figure 2.5). Their argument was that with a wooden pergola enclosing the door and one of the large windows on the southwest façade, this should be sufficient enough exterior solar shading to limit the direct solar radiation and overheating hours. But as the scenarios above have illustrated this is not the case. In order to fulfill the thermal indoor requirements in BR10 it is necessary with both external solar shading and cooling coil available when the temperature is too high. If it is chosen to continue with another scenario than number 2 the energy consumption for mechanical ventilation and cooling will increase unnecessary. The building program (byggeprogrammet) [Rubow] states that the building should live up to BR15 requirements resulting in an energy use of maximum 43.3 kWh/m^2 pr. year. In section 5.2 (Be10 energy calculation) it was also determined that establishment of approx. 25 m^2 PV panel would be necessary to decrease the amount of necessary external energy bought from the network and thereby meet the energy BR15 requirements. This means that the energy consumption is already pushed to the limit, so it is essential to choose the most energy sufficient solution of the three scenarios. Therefore, based on the results displayed in table 5.19 and 5.21

it has been chosen to continue working with scenario 2, with a reduction of 2.2 W/m^2 (~12 %) in the yearly simulation compared to scenario 3 with internal solar shading.

As reference it can be mentioned that the Esbensen Bsim model worked with VAV ventilation air change rates of op to 7h^{-1} during some periods of the the summer day and night. This involves a much larger ventilation system, both AHU and duct system than the scenario 2 from above. The Esbensen model, which was partially modeled, but not detailed by the author, did not fully comply with the number of overheating hours in BR10. In the following is a short calculation example illustrating why the cooling applied in scenario 2 is much more effective thatn the more than twice as high ventilation rate in a warm summer day situation.

Cooling effect is determinied by:

$$\Phi = \rho * C_p * q_v * \Delta T$$

Where
Φ: cooling effect [W]
ρ: density of air kg/m^3
C_p: specific heat capacity air [J/kg*K]
q_v: air change [m^3/s]
ΔT: change of temperature [K]

Volume: ~144 m^3
Air change (VAV): scenario 2: 3h^{-1} (incl. cooling); Esbensen's model: 7h^{-1} (no cooling).
Temperatues: max interior temperature when full load cooling (sc.2) or full load air change (Esbensen) is applied is 26°C during a warm summer day. In Bsim scenario 2 where cooling is applied the minimum inlet temperature is set to 18°C. In scenario without cooling and an maximum air change of 7h^{-1} the estimated exterior tempereture when the interior air temperature is 26°C is 24°C. These values are put into the cooling effect calculation:

Scenario 2 incl. cooling and ΔT: 8**°C**:

$$\Phi = 1\ \frac{\text{kg}}{m^3} * 1000\ \frac{J}{kg*K} * \left(\frac{3*144\ m3}{3600\frac{s}{h}}\right) *8°\text{C} = \underline{960\ \text{W}}$$

For scenario without cooling and max air change of 7h^{-1} and ΔT: 2**°C**:

$$\Phi = 1\ \frac{\text{kg}}{m^3} * 1000\ \frac{J}{kg*K} * \left(\frac{7*144\ m3}{3600\frac{s}{h}}\right) *2°\text{C} = \underline{560\ \text{W}}$$

This simple example illustrates that even with more than twice as high ventilation rate the actual cooling effect of this, is naturally not nearly as high as if cooling is provided to the inlet air. Obviously there are expences related to cooling of inlet air, but on the other side the ventilation system does not need to be dimensioned for an air change higher than 3h^{-1}.

5.5.3.2 Atmospheric indoor climate

The atmospheric indoor climate has to be checked by the CO_2 to make sure that the chosen scenario and ventilation strategy also complies with the requirements of maximum allowable CO_2 concentrations of 1000 ppm. Scenario 2 had a combined air change rate of $5h^{-1}$ available for mechanical and natural ventilation and the estimated air change rate of $5.1h^{-1}$ from the atmospheric requirements (section 5.3.11) based on an instant peak situation, is very close to this.

As the expected occupant user patterns from table 5.11 and 5.12 above illustrate, the internal heat load from occupants naturally reaches its peak points in the heating season, where most occupants are expected to be present in the common room for longer periods of time. Therefore a situation during that period is chosen to look into in regard to atmospheric indoor climate. Figure 5.16 illustrates the CO_2 concentrations in scenario 2 (VAV: $3h^{-1}$) in January.

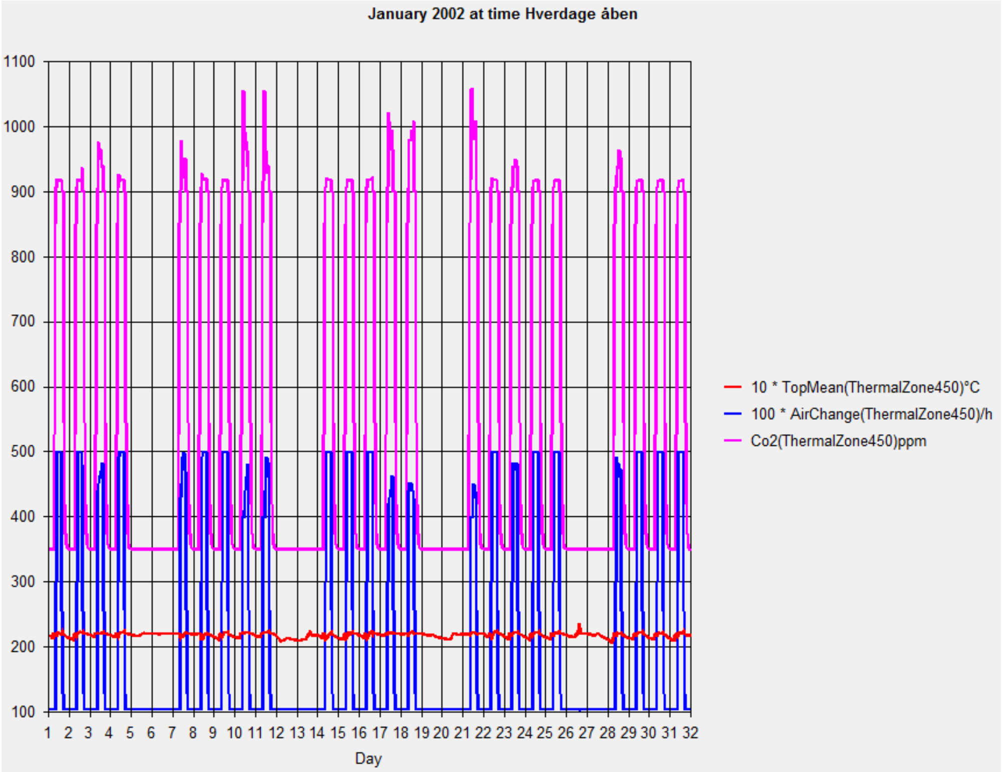


Figure 5.16 - CO_2 concentrations, air change and temperatures in common room 1 in January (TopMean: temperature operative mean).

The graph shows that during the weekdays the CO_2 concentrations relatively quickly approximate values of 900 ppm. and sometimes just over the limit of1000 ppm. for short periods of time. Over the course of a year the CO_2 concentration exceeds the allowable limit according to [THV1] 81 times, but never reaches values higher than 1060 ppm. This means that with a ventilation rate of VAV up to $3h^{-1}$ plus natural ventilation up to $2h^{-1}$, the scenario is within the limitation ~97% of the time, which is regarded as acceptable.

Scenario 2 seems to satisfy the thermal and atmospheric indoor climate requirements, and at same time require the least amount of energy of the three scenarios according to simulations made in Bsim. In section 6.4 comparisons with simulation in IES<VE> will be made.

5.5.4 Sum-up

Summarizing on Bsim as a simulation tool on the basis of this case study and previous projects carried out at Esbensen Consulting Engineers A/S.

Pros:

- Simulation process is quick and the analysis parameters are vast.
- Possibility of creating numerous rooms and thermal zones.
- Extensive list of building materials and possibility of putting together your own materials or elements.
- Many building system variations and combination possibilities.

Cons:

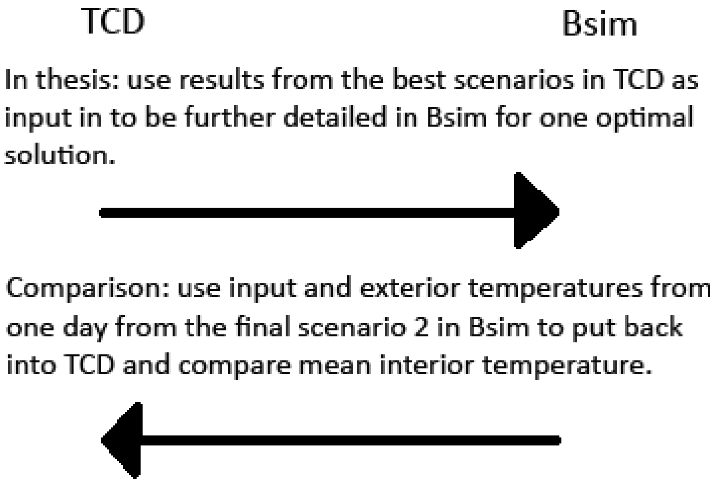
- It is not possible to import geometries from e.g. CAD files, so the user has to remodel, which is time consuming.
- The geometry construction interface with points and lines makes drawing and adjustment slow and tedious.
- Most often only representative rooms will be analyzed because the geometry construction and material assignment is very time consuming. This means that the engineer rarely gets to see the full picture of the interoperability of the whole building.
- Retyping of properties with e.g. all systems, when having more than one thermal zone or e.g. solar shading systems. It would be handy to have a way of selecting all similar components and streamline these with just a few settings.

Overall Bsim is a good and relatively well working simulation tool, but it is also relatively time consuming and non BIM based which the author believes limits its future position among the leading indoor environment simulation programs.

5.6 Comparison of results from TCD and Bsim

5.6.1 Method

Previously in the thesis, TCD was used as an early stage design tool by which estimations for a more detailed simulation program such as Bsim was obtained. However, despite the fact that TCD and Bsim are two very different programs in their detailing level, required input and operation system and consequently their output options, it is still interesting to compare results of similar scenarios and see how close they get to one another. This way, it is possible to evaluate the accuracy and reliability of TCD. Earlier in the report, results from TDC were used for estimation further detail in Bsim, in this comparison we go the opposite way, meaning that resulting inputs from Bsim scenario 2, are set in TCD for comparison (see illustration in figure 5.17). Keep in mind that TCD bases it calculation on one cloudless summer day with a mean exterior temperature of 21°C with a range of ± 6 °C. Originally the aim was to reach a mean interior temperature just below 23 °C, but in this comparison the two programs ability to reach the same mean interior temperature is investigated. However, it is impossible to find a day in the Bsim scenario that matches perfectly with the one in TCD, which is way the comparison is going backwards, and one day with fairly similar exterior conditions in Bsim scenario 2 is used for input in TCD, so both programs will be operation on the same conditions. In this context it should again be stressed that the two programs vast differences in term of operation and input parameters, makes it impossible to compare 1:1, but with some precautions simplified estimations can be made. In table 5.22 is a list of some of the main differences between the two programs which makes it complicated to perform and equal comparison.



In thesis: use results from the best scenarios in TCD as input in to be further detailed in Bsim for one optimal solution.

Comparison: use input and exterior temperatures from one day from the final scenario 2 in Bsim to put back into TCD and compare mean interior temperature.

Figure 5.17 - Illustration of project progress direction and way of working when comparing TCD and Bsim.

Because TCD states its results in mean operative temperature during one day, while performing this comparison, the day temperature variation from the Bsim scenario has to be combined as one mean operative interior temperature as well.

Table 5.22 - Main differences between TCD and Bsim in regards to this comparison.

TCD	Bsim
A) Calculation aimed at a mean temperature below 23°C	A) Simulation aimed at fulfilling requirements of BR10 of overheating hours during one full year
B) Result: main operative temperature of one day	B) Result: annual simulation with numerous result parameters
C) Set time for natural vent. 7a.m.-5p.m. (all day)	C) Set temperature for natural ventilation at 20°C during all day
D) Set time for HVAC 7a.m.-5p.m. (all day) and cooling 5p.m.-7a.m. (all night)	D) Set temperature and CO2 concentration for HVAC and set temperature for cooling night and day*
E) CAV in each time interval**	E) VAV, changeable according to current conditions in the room
F) Internal gains are less flexible during the day	F) Internal gains are flexible due to time profile that can vary often during the day
G) Basis its calculation on a cloudless summer day with min 15°C and max 27°C.	G) No completely cloudless day, but on the chosen one it is very close to an the solar radiation and temperature match well to TCD
*See table 5.17 and 5.18. (mechanical vent. and cooling)	
**Ventilation is constant at 3h-1 mech. vent. + 2h-1 natural vent. during day and 3h-1 mech. vent. during night.	

5.6.2 Case

The chosen day from the Bsim simulation (which basis it weather data from the DRY year weather profile), and has relatively similar exterior conditions as the one from the TCD scenario, is the 10th of July (3th day in week 28). On this day the in Bsim the exterior temperature profile has hourly values in an interval from 13.0°C to 29.2°C, with a mean exterior temperature of 21.1 °C. On the chosen day, it is not completely cloudless, but the solar radiation is relatively high as seen in figure 5.18. These weather inputs and the inputs for ventilation are set in TCD in a tailored scenario, so the mean exterior temperature in the two programs is similar. The ventilation values transferred to TCD from Bsim scenario 2 are 3/ 2/ 3 [h^{-1}] meaning mechanical ventilation during day, natural ventilation during day and mechanical ventilation and cooling during night respectively. However, a major difference is that the ventilation type in Bsim is VAV in and in TCD it is CAV, which is especially significant in regard to the way in which cooling is applied. In Bsim cooling is applied during day, if the interior temperature exceeds 24°C, and at night this temperature is set to 22°C with a minimum inlet temperature of 18°C. In the tailored TCD calculation cooling is applied during 4 hours (based on qualified guess on the amount of hours in the opening period above 24°C, because set point is not incorporated), of the day at 18°C without interior temperature considerations. During night the room is mechanically ventilated with the average temperature over this period of 17.2°C. All mechanical air change rates in TCD are $3h^{-1}$ and natural ventilation is $2h^{-1}$.

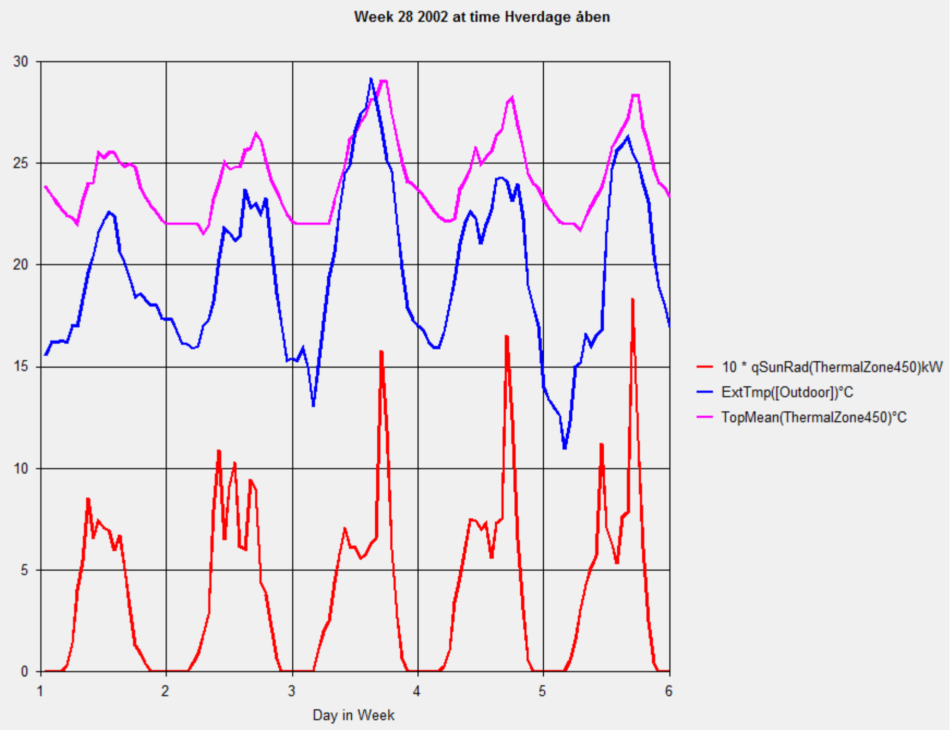


Figure 5.18 - Illustration showing that the solar radiation (qsunrad) being relatively high on the chosen day, 10th of July (3rd day of week 28).

5.6.3 Results

With the stated input the following results are obtained in tailored TCD calculation:

Table 5.23 - Tailored TCD scenario, sf: 0.2. Ventilation: 3 /2 /3 [h^{-1}] (4 hours 18°C cooling during day + natural ventilation and night is ventilated with the temperature of the average temperature during night, because of lack of set point for ventilation).

Mean temperature over 24 hours period	°C
No solar shading:	27.1
Inc. time-dependent solar shading ext.:	24

In table 5.24 the mean interior temperature of the tailored TCD scenario is depicted with the mean interior temperature of the Bsim scenarios. Values from all three final Bsim scenarios are depicted just for comparing purposes because they all have same exterior conditions on the chosen day.

Table 5.24 – Results from TCD tailored and Bsim compared.

Scenario	°C
TCD tailored (comparison scenario)	24
TCD mean ext. temp.	21.1
Bsim SC. 1	25.4
Bsim SC. 2	24.5
Bsim SC. 3	24.3
Bsim mean ext. temp.	21.1

For comparison the above result are illustrated in figure 5.19.

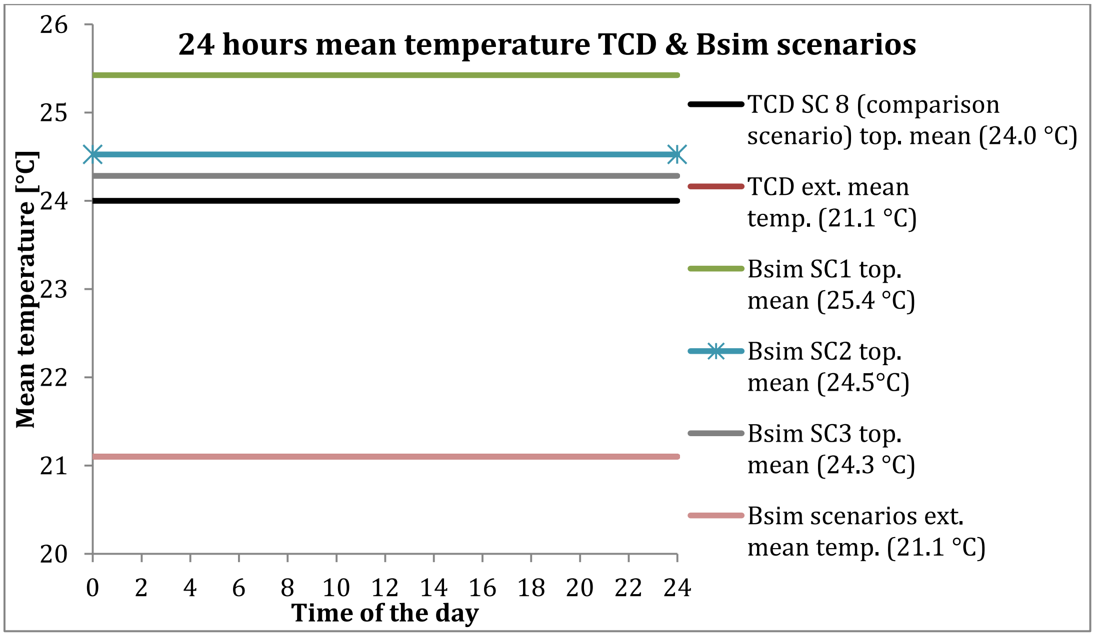


Figure 5.19 - Results of the tailored TCD scenario with input values similar to Bsim scenario 2 compared to the mean interior temperatures of the three Bsim scenarios (all with similar exterior conditions). (The two exterior conditions at 21.1 °C are illustrated by just one graph line). (SC: scenario). (The line with the crosses on indicates Bsim scenario 2, which are the basis of the comparison).

In figure 5.19 it is seen that with the many precautions and estimations explained in the two programs come to a mean 24 hours day temperature no more than 0.5°C apart from one another. However, the reliance of this comparison can be argued, because of the many estimation e.g. the number of hours the cooling system runs on full load during the day, the difference in control etc.

Figure 5.20 illustrates the same TDC and Bsim scenarios as above, but this time the Bsim scenarios are illustrated with hourly values of operative temperature over the course of 24 hours. This comparison is made to illustrate how the Bsim hourly values develop during the chosen day compared to the mean operative temperature form TCD.

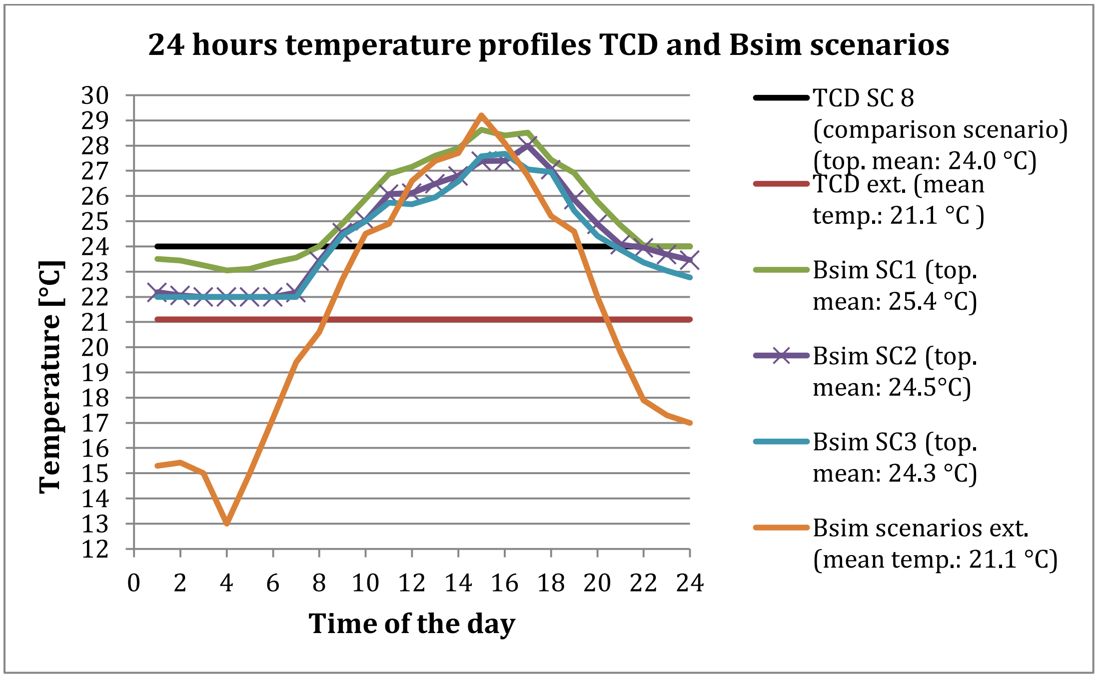


Figure 5.20 - Illustration of the tailored TCD scenario and the three Bsim scenarios over the course of 24 hours on a warm summer day. (Top.mean: mean operative temperature). (The line with the crosses on indicates the preferred Bsim scenario 2).

Figure 5.20 illustrates how Bsim scenario 1 is above the TCD mean indoor temperature the majority of the time. During the day, the same is true for Bsim scenario 2 and 3 but their lower night temperatures compensates a little bit for this and results in average temperatures as written next to the graph in figure 5.20. Additionally, it is seen in figure 5.20 that on this particular day all three Bsim scenarios have interior temperatures above the 26°C and 27°C threshold values from BR10. However, as previously stated, scenario 2 fulfills the requirements from BR10 over the course of a year as were the goal in Bsim.

Based on this one comparison example it is seen that when using the stated comparison approach and precautions (which obviously cause some uncertainties), the two programs gives mean interior temperature results relatively close to each other (0.5°C).

Generally it can be concluded that TCD calculates fairly accurate, but it is also very simple and the author feels safe to say that TCD, as in this case, can serve as a good indicative tool to perform early estimations and test various scenarios at the early design stages. Even though TCD operates very different and none of the scenarios from TDC directly fulfilled the BR10 requirement when used in Bsim, inputs from the best scenarios in TCD can still serve as indication of e.g. necessary air change rates, cooling and external solar shading in Bsim.

5.7 Non-BIM model exchanges

Much of the focus of this thesis revolves around the use and outcomes of mainly two different model exchange processes in relation to BIM (Revit to IES<VE> and Solibri) details of these can be found in the following section. For the sake of providing a wider perspective of alternative approaches regarding reuse of model geometry in relation to building analysis on energy and indoor climate, two additional considerably simpler exchanges have been looked into. The first one is exchange from AutoCAD → IES<VE> and the second is from SketcuUp → IES<VE>. These are both non BIM based exchanges because the sender program is non BIM based and e.g. does not support the IFC format. However, the latter exchange converts into gbXML similar to the exchange from Revit → IES<VE> with the same kind of information attached.

The first exchange from AutoCAD enables 2D plan drawings to be transferred into IES<VE> with no information attached whatsoever[5].The process can be described in three easy steps:

1) Write a unique room ID in each room in the 2D AutoCAD plan drawing in regular text mode and explode ID text afterwards (This ensures that each room has a room ID to be used in the model browser in IES<VE> later).
2) Export the file as a “2004.dxf” file.
3) Import the dxf file and choose “create dxf” icon in the right corner of the IES<VE> ModelIT display. This opens a pup up menu which prompts the user for a room height and when applied this makes the 2D floor plan into a 3D model in the ModelIT application*. The room definitions are then added to the model browser and the user may work on this as any other geometry model.

*As the “create dxf” feature is a very new it is only available in the not yet released IES<VE> “Alpha 5” version. In other version of the programs the import only brings up a background image of the 2D floor plan which the user has to draw on top of.

This process is completely non BIM based because of no information attached. It may save time on measuring/ redrawing of the plan but all attributes such as doors, windows roof inclination etc. has to be modeled in IES<VE> because they were never part of the exported 2D floor plan in AutoCAD. In reality the author does not see the big potential in this process because it only just transfers a simple floor plan.

The process is illustrated in figure 5.21:

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[5] Taught to Lasse Brandt and Oliver Franck at IES in Scotland and passed on to the author.

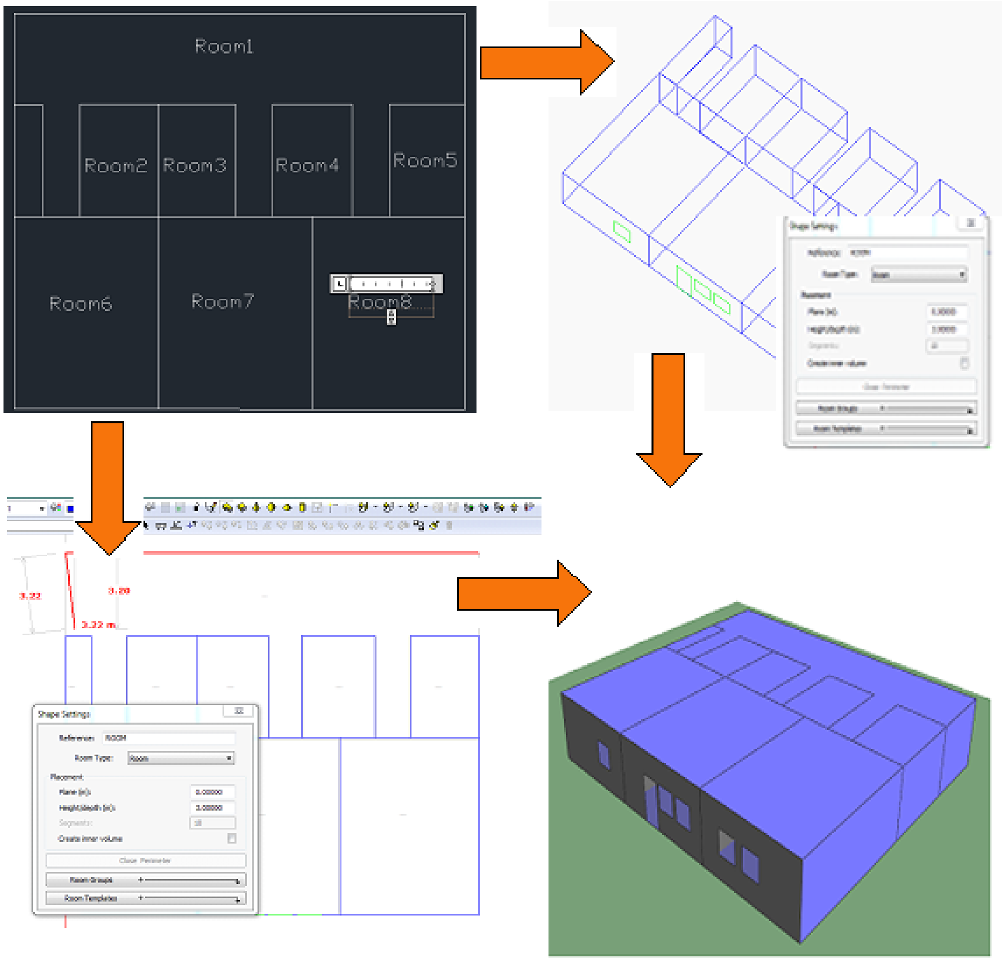


Figure 5.21 - Export from AutoCAD to IES<VE>. Top left: simple AutoCAD plan drawing with input of room ID are exported as dxf. Top right: the extrusion of the model by use of the Alpha 5 "create dxf" function with dialog box for determining room height (windows and doors are inserted separately afterwards). Bottom left: redraw on top of the imported background floor plan. Bottom right: result of imported model geometry by either redraw or extrusion method.

The second exchange enables a 3D SketchUp model to be exported for analysis in IES<VE> through the plug-in IES has created for SketchUp and includes building location and building component types similar the exchange from Revit → IES<VE>. The process can be described in four simple steps:

1) Activate the "locate rooms" icon in the IES<VE> plug-in in Revit and the program identifies any rooms located in the model and provides it with a room ID.
2) Set geographical location and building component types from the predefined component database.
3) Choose "thin" or "thick" wall type determining whether the model's walls has any volume, if the model choice is thin wall the user has to be aware that when later applying building materials in IES<VE> these will have their starting point at the exterior

side of the construction and fill up inward thus decreasing the remaining room size. If thick wall type is chosen the model should be modeled according to this.

4) Press the “Launch VE” to export the SketchUp model and IES<VE> is automatically opened with the imported model geometry, room definitions and attached building component types ready for further work. This plug-in handles the odd room and skylight geometry without problems.
   The process looks as follows:

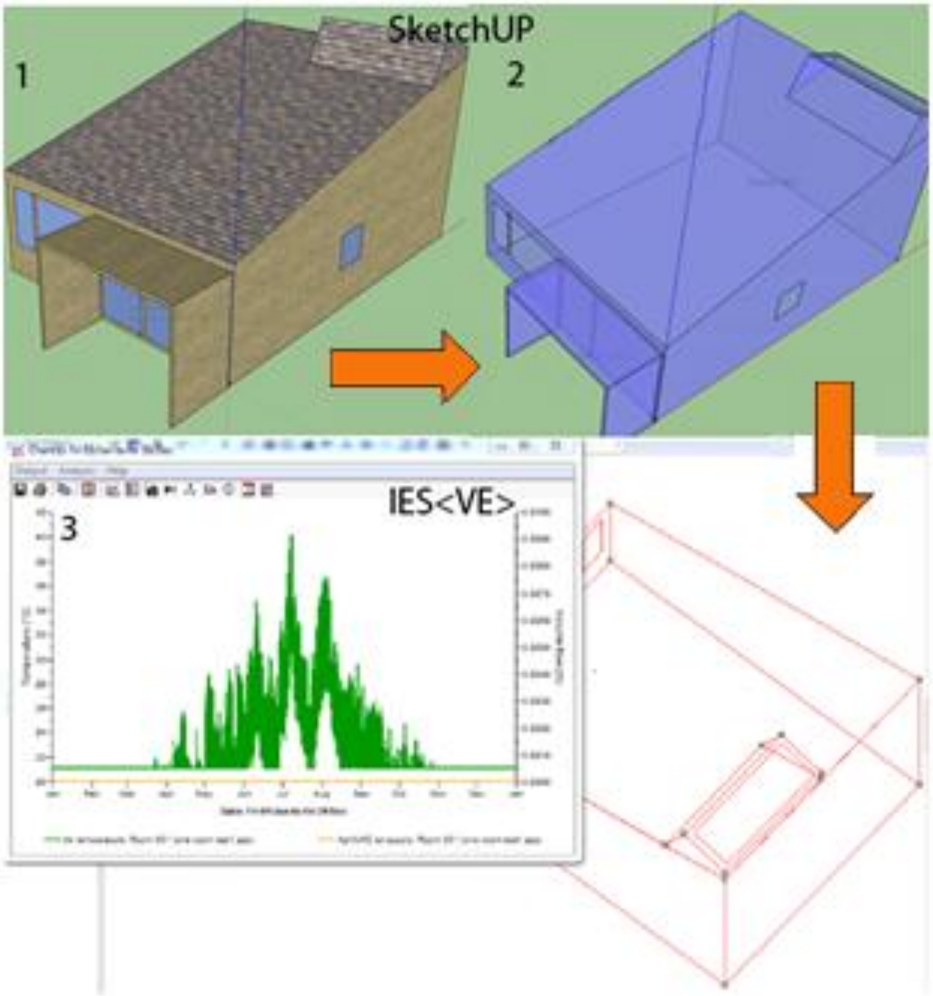


Figure 5.22 - Export of model from SketchUp to IES<VE>. 1) SketchUP model, 2) room ID located SketchUp plug-in and the model is converted to a gbXML file, 3) imported model in IES<VE, illustration shows results from a simple test simulation.

If a proper SketchUp model is available this process is by far the easiest and most efficient way of transferring error free model geometry with or without attributes that the author has come across. As something relative unique with SketchUp, it is possible to export a model back into this from IES<VE> for geometry modifications but this requires the pro-version of SketchUp. However, since SketchUp is non-BIM based a model made here cannot be exported into Solibri Model Checker.

6 Case study – Model Based Workflow

This section investigates the model export process from the architectural design model in Revit to building analysis in IES<VE>. Furthermore, Solibri is used to locate issues and coalitions in the model and what possibilities this software poses for the collaboration between the architect and building service engineer. Finally, indoor climate, energy consumptions and daylight analysis (although illustrated earlier), are made in IES<VE> and used in the overall focus of the thesis.

6.1 Model transfer Revit to IES<VE>

6.1.1 Method

One of the major advantages of the BIM working approach (also referred as MBW earlier), is the knowledge sharing between disciplines in a building project which leads to many derived benefits. Of course, with something as complex and used across such a broad professional fields, it is vital to have certain guidelines of, which information is to be passed on to whom and when as is the intention of an IDM (refer to section 3.2). Nevertheless, the file format and the way the BIM model is created are also absolutely essential for the information transfer and interoperability between programs [IES-VE 2010].

This thesis focuses on the collaboration/exchange between a building's architectural design model and its energy and indoor environment simulations model and how if these two models can work together in the integrated design process. Therefore the interoperability between Revit and IES<VE> is tested through the plug-in IES has created for Revit which converts the rvt (Revit) format into a gbXML format. On IES´s website [IES-VE] are some design exchange guidelines [IES-VE 2010] ready for download, which illustrates how to create a transferable 3D Revit models, and these guidelines must be complied with very carefully in order for the export to IES to work.

IES admits that there are limitations to the plug-in and emphasizes that if the design team has a planning meeting prior to project startup, the engineers can, at that point let the architects know how they wish the building to be modeled by providing the IES guidelines and thereby saving loads of time and money for both parts by neither of them having to remodel [IES BIM 2011].

IES describes the ideal workflow from 3D model to finished energy and indoor environment model in the four following steps:

1) Design	(Revit)
2) Translate	(IES<VE>'s plug-in)
3) Analyze	(IES<VE>)
4) Carry further	(other BIM based programs)

The essence of IES's guidelines is found in three main areas:

- The way in which the rooms must be defined and bounded
- The definition of the construction parts that enclose the rooms

- The project information such as geographic location

When converting the model into a gbXML document the information stored in the model is organized in the order illustrated in figure 6.1:

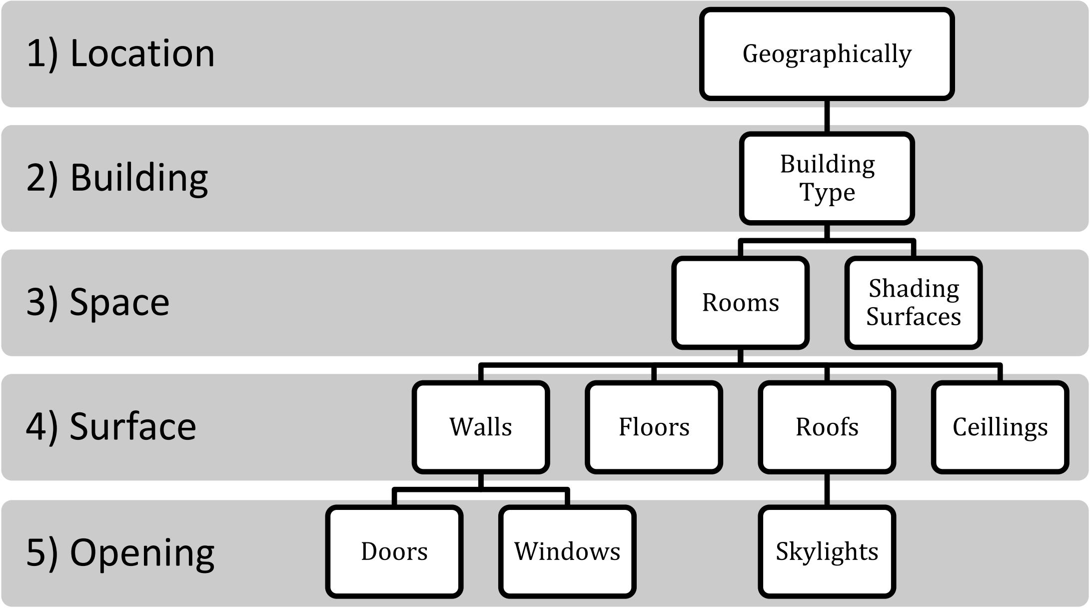


Figure 6.1 - gbXML file hierarchy diagram.

Brief description of figure 6.1 and guidelines:

1) Location is set in the “set model properties” dialog box in plug-in and transferred in IES (see figure 6.3).
2) Building type set from a predetermined list in the plug-in in “set model properties” dialog box.
3) Spaces must be correctly defined horizontally and vertically within a set of walls, floor and ceiling. This can be done either by zone-based modeling (early stage design) or room-based modeling (more detailed or with different thermal zones adjacent to one another (the latter one was used in this case)).
   Shading surfaces are surfaces such as overhangs, or in this case the pergolas in front of the façade, which do not directly affect the thermal calculation. These are included as non-enclosures and only provide shade.
4) Each construction element such as wall, floor etc. must an enclosed room volume and be defined as “Room bounding” otherwise it will not transfer to IES. In figure 6.2 are an example of an assigned room (blue highlight), and its corresponding ceiling with and without “room bounding” defined. In addition, the lower and upper boundary of the room can be set in case it needs an offset from a construction component such as a floor slap.

5) Openings are so called “hosted components”, which must be assigned to another component and defined as a door, a window or a skylight, if they are not defined correct the room will extend beyond the boundaries of that element [IES-VE 2010], [IES plug-in].

Further, when exporting a model, it is important to set the gbXML for a proper complexity level. There are five different complexity levels to choose from, determining the amount of detail to include in your export, for most projects IES advise that the “simple” one (complexity level 1) is sufficient and reduces simulation time later on, because it ignores or combines very small geometries by determining the tolerance level of the export. This will be followed up on later in the example of window fenestrations, when going into IES<VE>. However, since it is important to include the pergolas outside the façade windows in terms of daylight conditions, in this thesis the chosen complexity level is the “simple with shading surfaces” (complexity level 2). Additionally, in order for the building volumes to be accurately exported, the user must go to “Room and volume computations” and make sure that this is defined as “Areas and Volume” as opposed to the default “areas only” (see appendix L) [IES BIM 2011] otherwise export ends up without proper boundaries.

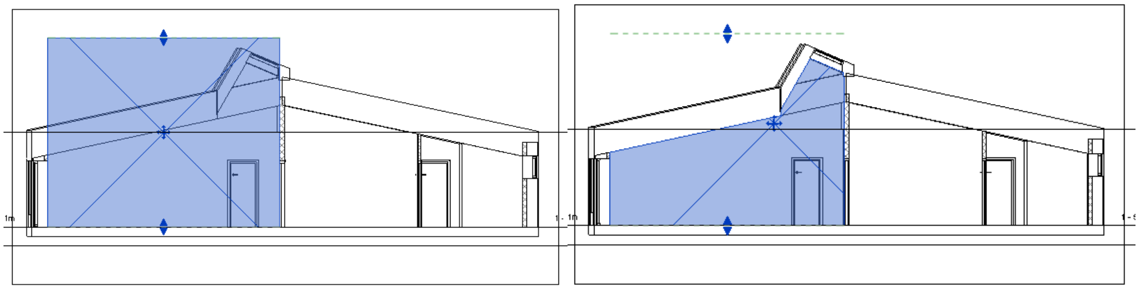
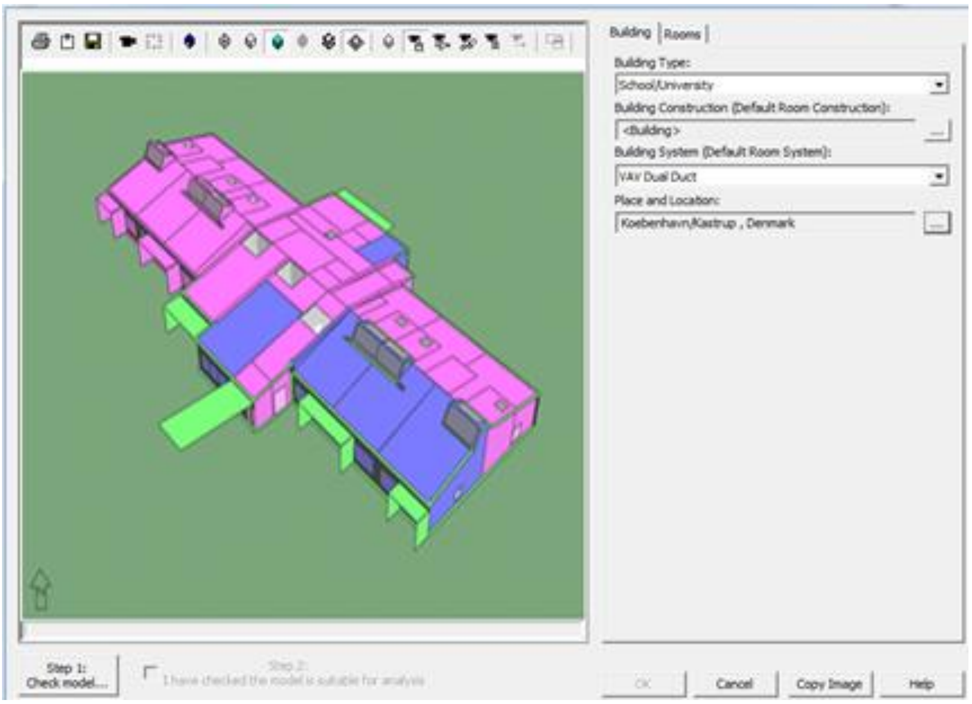


Figure 6.2 - Example of room definition. Left: the room (with the blue highlight) is defined horizontally but not vertically bounded by the roof construction. Right: the same room is correctly bounded by the ceiling which encloses the room.



Building Type: School/University

Building Construction (Default Room Construction): <Building>

Building System (Default Room System): VAV Dual Duct

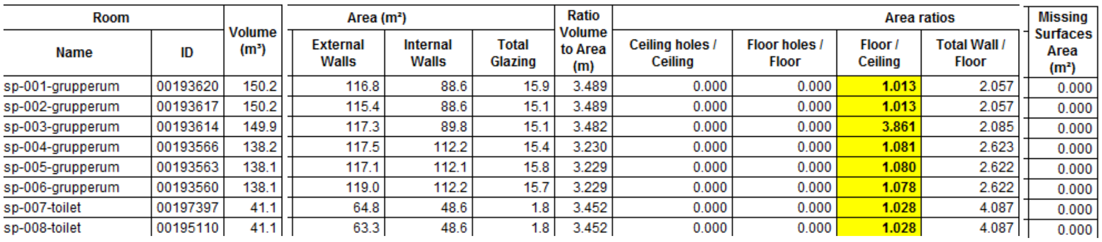
Place and Location: Koebenhavn/Kastrup , Denmark

Figure 6.3 – Final version of the simplified model for export – “Set model properties” dialog box. The blue rooms are the simulated rooms. Top: kitchen (northeast); left: the main kitchen (southwest); right: the three common rooms (southwest). The pink rooms are the non simulated rooms set as “adjacent” and the green parts are the shading wooden pergolas.

In the “Set model properties” dialog box the final settings can be made and the user is prompted to visually inspect and accept the corresponding IES Report sheet illustrated in figure 6.4. Ideally, the IES Report should not illustrate any highlighted boxes because these represent geometry errors of some sort, for instance unclosed gaps between the wall and the ceiling. This report gives an indication whether there are any issues with the model, but it does not specify it more precisely than the room, surface and type of error of question. There are no further details on where more precisely on a given surface or intersection between surfaces to look for the issue for correction. This issue will be addressed further in the Solibri section later. In this case, the IES Report for export from Revit, showed only highlights in the floor/ceiling ratios illustrated in figure 6.4, which is due to the tilted ceiling and is no raise for concern. Aside from the IES Report the “Set model Properties” dialog box allows the user to input model data regarding:

- Building type – office, dwelling, school etc.
- Choice of building components type from a predefined (non-editable) building component database within the IES<VE> plug-in (will come back to this in the IES<VE> section)
- Building system – ventilation system type
- Geographical location

After these properties have been set, the import to IES<VE> through the plug-in can take place and IES<VE> automatically pups up with the imported model opened.



Room		Volume (m³)	Area (m²)			Ratio Volume to Area (m)	Area ratios				Missing Surfaces Area (m²)
Name	ID		External Walls	Internal Walls	Total Glazing		Ceiling holes / Ceiling	Floor holes / Floor	Floor / Ceiling	Total Wall / Floor	
sp-001-grupperum	00193620	150.2	116.8	88.6	15.9	3.489	0.000	0.000	**1.013**	2.057	0.000
sp-002-grupperum	00193617	150.2	115.4	88.6	15.1	3.489	0.000	0.000	**1.013**	2.057	0.000
sp-003-grupperum	00193614	149.9	117.3	89.8	15.1	3.482	0.000	0.000	**3.861**	2.085	0.000
sp-004-grupperum	00193566	138.2	117.5	112.2	15.4	3.230	0.000	0.000	**1.081**	2.623	0.000
sp-005-grupperum	00193563	138.1	117.1	112.1	15.8	3.229	0.000	0.000	**1.080**	2.622	0.000
sp-006-grupperum	00193560	138.1	119.0	112.2	15.7	3.229	0.000	0.000	**1.078**	2.622	0.000
sp-007-toilet	00197397	41.1	64.8	48.6	1.8	3.452	0.000	0.000	**1.028**	4.087	0.000
sp-008-toilet	00195110	41.1	63.3	48.6	1.8	3.452	0.000	0.000	**1.028**	4.087	0.000

Figure 6.4 - Example of a section of corresponding IES Report to be checked prior to export.

6.1.2 Case

In this thesis, based on a daycare institution, which was originally in collaboration with Rubow Architects and Esbensen Consulting Engineers, Rubow has provided a Revit model. Esbensen, who did not work with Revit or BIM in any matter, requested drawing material in regular 2D AutoCAD format, which means that the Revit model is only intended for use by Rubow. All drawings, models and other relevant material from each business partner is shared through a Dropbox folder. The CAD drawings provided by Rubow have been used as the basis for the Be10, TCD, Daysim and Bsim calculations. The 3D Revit model has been used for the transfer of geometry into IES<VE> according to the procedure described in section 4 (method). Due to the fact that the author has been effectively cut off from the real case, it is unclear exactly by which means and with which intentions Rubows Revit model has been modeled. The Revit model is most likely only intended for visual presentations, documentations etc. and the structural engineer at Sloth Møller in charge of the case was contacted to check if they had been able to use the Rubow Revit model for transfer. However, since the project is relatively simple seen from a static point of view, with only one storey the project was estimated to be too little and simple in its construction to spend time on transfer of the Revit model into a BIM capable software. It is a weighting of effort and time vs. gains, and in this case it was considered to be more time spend during the process than the expected gains could justify[6].

So as it turns out the provided Revit model was never intended to be used in a BIM context, nor defined according to modeling guidelines such as those provided by IES, and therefore not intended to be transferred into an energy simulation program. This is very evident when opening the model, because there are numerous minor holes in the building envelope and errors of all sorts when looking at the details. That is why, instead of having the architect model according exchange guidelines, the author had two choices for modeling and exporting to IES<VE>:

A) Work the opposite way and try to repair and simply the original 3D Revit model.
B) Redraw the building from scratch in Revit on top of an imported AutoCAD plan drawing.

Eventually both approaches were investigated and are described in the following.

---

[6] Source: phone call with the responsible static engineer on the case from Sloth Møller.

6.1.2.1 Repair and simplify approach

With the intention of sticking with the BIM concept of eliminating remodeling, approach “A” was chosen as first choice for further work. In appendix L are illustrations of the original Revit model and the gbXML file illustration, figures of a few adjustments made in the process, and the final Revit and gbXML model. This repairing approach should however, prove to be much more complicated than anticipated, because the geometry of especially the roof construction, skylights and changes in the façades longitudinal direction were not modeled very consistently in terms of room definition and joining of different roof elements. This caused all sorts of errors and warnings in the transferring process to gbXML. Since the IES Report does not specify location of the issue very precisely, the author investigated the model in detail and located and corrected a large number of geometric inconsistencies.

The following is a sum up of main corrections made to the original Revit model, but it is not a detailed walk through of all changes made. This seems to be very tedious and a bit irrelevant when the reader can refer to IES´s guidelines, even though this process has been very informative and extremely time consuming for the preparation of the thesis. Instead, some examples of the main changes/ corrections made to the model are listed below and supplemented by figures and descriptions in appendix L:

- The architects shared the original Revit model with restrictions on it, which made sure that only they could alter the model. This meant that the model had to be “detached from central” in the opening menu of the Revit program prior to any adjustments otherwise the model would be a so called “read only” model.
- The entire model had to be cleaned and simplified from BIM information level 3 to information level 2, so only the building geometry including doors, windows and internal room partitioning would remain. If there is any positive aspect of cutting all attached information away from the Revit model, it would be that the file size is significantly reduced thus easier to transfer. But it would be much more preferable if the information already assigned to the model could have been understood by the plug-in and transferred along with the geometry.
- Redefining a large portion of the building envelope construction parts to be room bounding and all rooms to be defined within a set of enclosures because gbXML files only converts what is defined as rooms with boundaries plus possibly shading surfaces, depending on the complexity level chosen for the transfer in the plug-in.
- Remove the ventilation room on the first floor in the building’s middle section because it caused countless errors with the walls beneath and the room itself is not important for the building performance analysis.
- Move room separation lines from conflicting with interior and exterior walls.
- The original skylight construction was made as a family on top of the roof causing peculiar openings in the geometry and would not connect to the rest of the roof. Both of these issues would only be visible in the gbXML file and not in the Revit model thus very difficult to solve in Revit. Two solutions to this problem became apparent: A)by

slightly reducing the angle of the surface where the skylight is located and increasing the width of the skylight construction it is possible to avoid these odd openings in the back of the construction and combine roof and skylight construction (see figure 6.5). (This option was found through advice from a forum on Revit´s website and by analyzing the model in Solibri). B) Leave the problem and solve it later in IES<VE> by deleting the extra opening. (More on this issue can be found in the Solibri Model Checker section).

- With the skylight construction working and converting well into gbXML format the model could be exported to IES<VE> for further work and analysis.

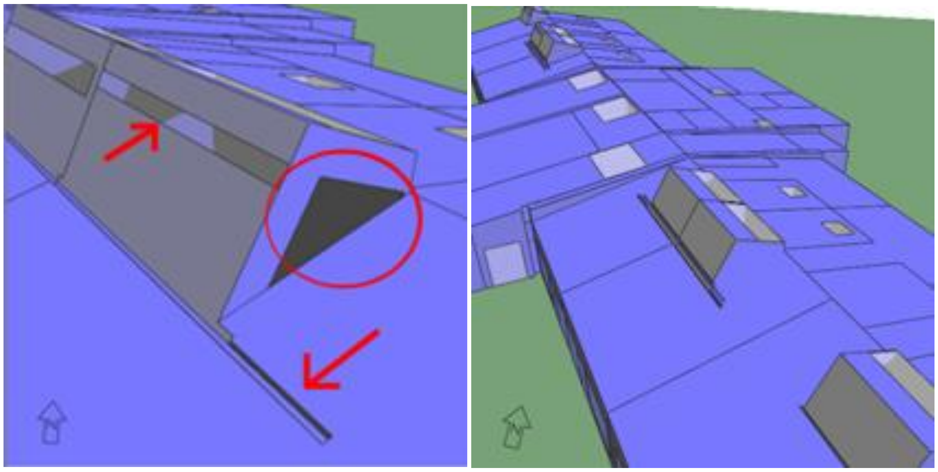


Figure 6.5 - Left: illustration of the problem with the skylight construction. The left arrow shows an opening made in the transfer to gbXML file which is avoided in the final version (illustrated on the right in IES<VE>). The circle shows an unwanted opening on the side and the right arrow is the issue with the two roof pats not joining correct. Right: the final converted gbXML file.

6.1.2.2 Remodel approach

Since fixing the original model to something usable for energy simulations was much more cumbersome and time consuming than initially anticipated, the author wanted to test approach "B"– redrawing the model from scratch, for comparison. The redrawing of the model has been made in accordance with IES´s guidelines a with an AutoCAD plan drawing of the daycare institution as underlay for the model. Only the southeastern 1/3 of the building consisting of three common rooms and adjacent facilities has been redrawn as a test. This model converted as supposed to because the building elements was assigned as room bounding and the rooms were properly defined. In appendix L are illustrations of this transfer approach.

One more test was made with a simple rectangular shaped building model of DTU building 118 also designed according to the IES guidelines. Again, this model encountered no problems converting correct to gbXML (see appendix L). Most issues seem to occur when the geometry gets a little tricky, such as the skylights construction combined with a tilted roof. If a model is intended for transfer to a building simulation program such as IES<VE>, the designer has to be very careful on how to set boundaries and define room geometry.

6.1.3 Experiences gained and discussion

Working backwards on an existing Revit model and preparing it for export into a building analysis program, can be very complicated and require extensive model modifications. This is a very time consuming process and should not be underestimated. As IES suggests: "*sometimes it is just easier to redraw the whole thing as opposed to start correction an existing model*" [IES BIM 2011]. In this case the author initially estimated that due to the relatively small building, the amount of necessary changes would concurrently be limited. However, reflecting on this afterwards, the author must acknowledge that unless the user knows exactly what to look for and how to repair every detail, it is almost impossible to correct a model 100 percent.

Redrawing the model is exactly the opposite of the intention with BIM, and for that matter one might as well have used only 2D drawings and non BIM based software, because the original model is not converted from design to analysis model. However, in this case with an architectural 3D model, which was not set up to be converted into a building simulation program, the redraw approach was actually the easiest and by far the quickest way to obtain correct and usable geometry created in Revit and ready for transfer into IES<VE>. This emphasizes the fact that all parties in a building project has to communicate and agreed on the type and level of detail of shared information each partner needs, and preferably express this in the project IDM.

The conversion from rvt into a gbXML file reduces the file size to roughly 10% of the original rvt file size, which gives an indication of how much/little information is actually converted into the gbXML file, to be used in a building analysis program. The exported model only contain room volumes, surface geometry and limited building component information, which can be assigned in the plug-in based on a predefined building component list. This means that the plug-in is not able to convert the information already put into the Revit model by the architect. For the conversion to take place the model has to be stripped for any "superfluous" information aside from the geometry that the plug-in does not understand. Furthermore, since the plug-in only contains a certain predefined list of building components when the model is imported to the chosen building analysis program all building components has to be designed and attached to the model once again.

Overall the level of detail in the converted file is very limited and inadequate for full use of BIM workflow, even when considering the extra attributes the user can input in the "Set model proberties" dialog box illustrated in figure 6.3. This leads to the conclusion that the ideal situation where only one BIM model, shared between all business partners on a given project is not (yet) realizable. Instead it is much more likely to have a scenario with specefic dicipline models and one main aggregate model (a process which more software providers suggest) [IES BIM 2011]. With the rescrictions experienced in terms of exchanged informations from design to simulation tools, the following is an example of the practical use of these building model types: One main conceptual model is detailed up until BIM information level 2 with respect to inputs and considerations from all disciplines involved making sure that none of these are neglected. From this stage the model is split up into an aggretage (architectural) model and several dicipline models. The aggregate model will then be detailed, as it would have anyway up until BIM information level 5 or 6 and each dicipline model is modified for its specific purpose, but the geometry remains unchanged in thise. If or when a significant project change affecting more than one subject takes place, all business partners needs to be informed and the corresponding models would have to be adjusted concurrently. Any inconsistancies between any of the models can conveniently be located through model compliance software such as Solibri. The proposed process is illustrated in figure 6.6.

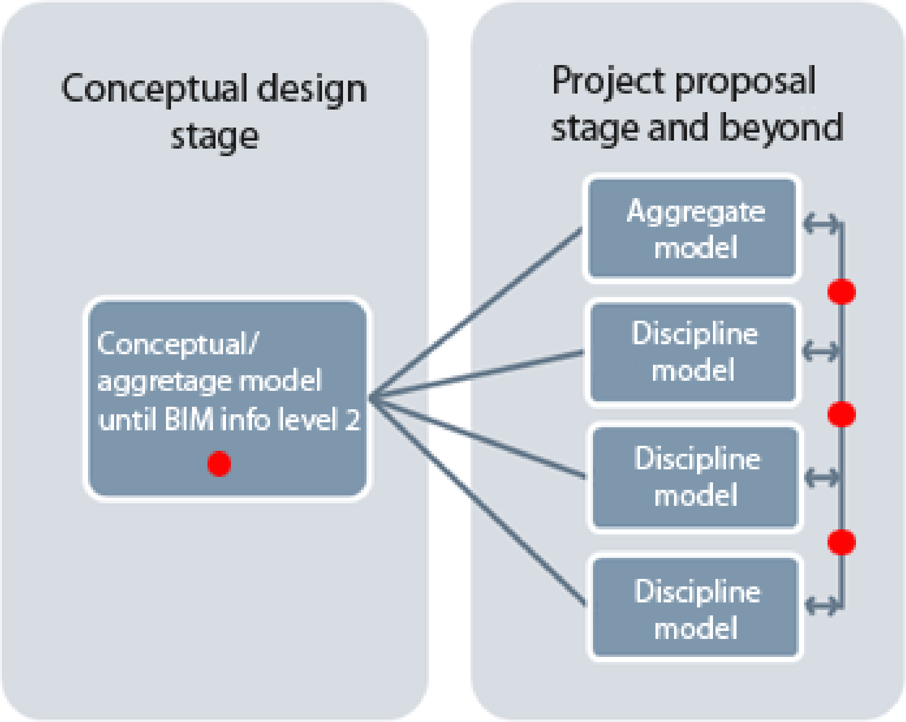


Figure 6.6– Proposed model sharing process.

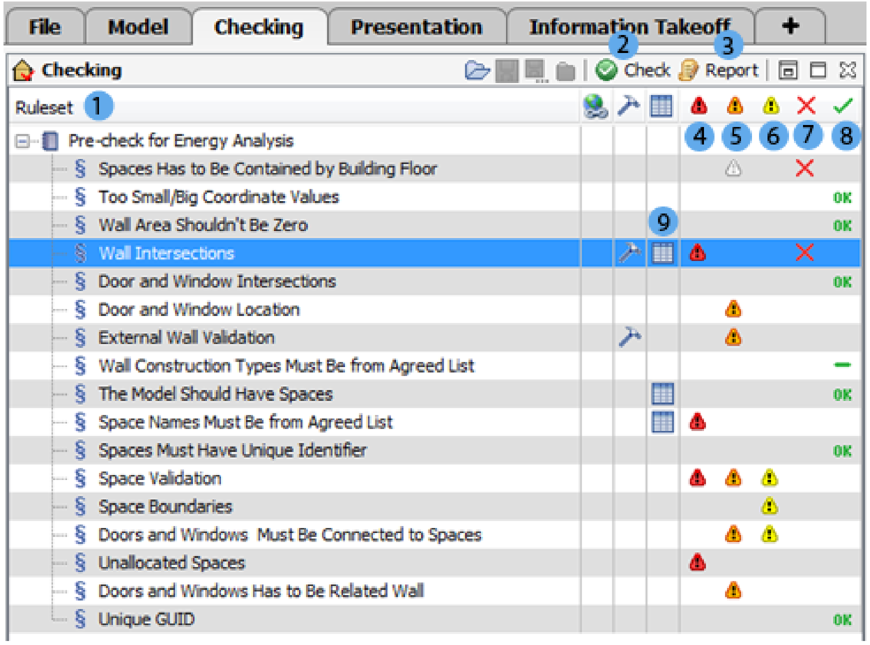
Figure 6.6 illustrate the process where one conceptual aggregate BIM model is used until information level 2, where after this is divided into an aggregated model and discipline models used for analysis with various purposes. The red dots in figure 6.6 illustrate suggested times to perform a consistency check in e.g. Solibri model checker (see more on this in the next section).

6.2 Consistency model check

In the process of correcting the original architectural Revit model for export to IES<VE>, various ways of getting around certain geometric problems, especially with the skylight construction, has been investigated. Besides correcting directly in Revit, an alternative approach was to bring the Revit model into Solibri and test it against a relevant ruleset and thereby see if the errors highlighted in the IES Report would be located visually by specific construction part and not just by category and corresponding room.

6.2.1.1 The case

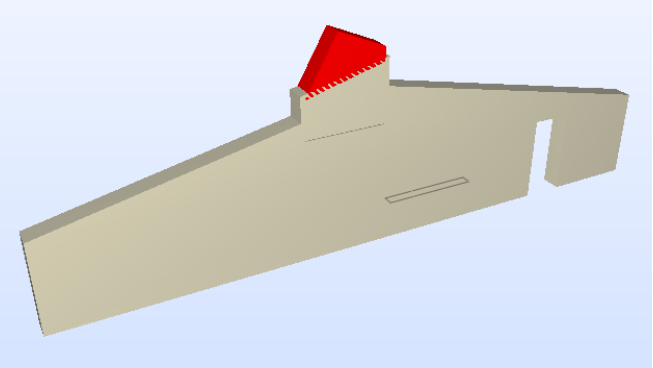
In this thesis the simplified model from the case has been imported as an IFC (2x3) file in Solibri, wherein the models were first visually inspected for correct imported and minor adjustments were made in the “Model” section. Going on to the “Checking” section, which is the analysis section of the program, each model has been checked against a predefined BIM validation ruleset as well as an energy analysis ruleset. Due to the large number of rule violations as can be seen in figure 6.7, it has been chosen to focus work on and violations in regard to the BIM validation ruleset.



Ruleset 1	🔨	▦	⚠ 4	⚠ 5	⚠ 6	✗ 7	✓ 8
Pre-check for Energy Analysis							
§ Spaces Has to Be Contained by Building Floor				⚠		✗	
§ Too Small/Big Coordinate Values							OK
§ Wall Area Shouldn't Be Zero		9					OK
§ Wall Intersections	🔨	▦	⚠			✗	
§ Door and Window Intersections							OK
§ Door and Window Location				⚠			
§ External Wall Validation	🔨			⚠			
§ Wall Construction Types Must Be from Agreed List							–
§ The Model Should Have Spaces		▦					OK
§ Space Names Must Be from Agreed List		▦	⚠				
§ Spaces Must Have Unique Identifier							OK
§ Space Validation			⚠	⚠	⚠		
§ Space Boundaries					⚠		
§ Doors and Windows Must Be Connected to Spaces				⚠	⚠		
§ Unallocated Spaces			⚠				
§ Doors and Windows Has to Be Related Wall				⚠			
§ Unique GUID							OK

Figure 6.7 - Example of the simplified model before finished from the checking section in Solibri. The blue circles explain important functions of the program. 1) The selected ruleset (energy analysis), 2) Check start, 3) Print of report to Excel, 4) Severity level high, 5) Severity level moderate, 6) Severity level low, 7) not accepted issue, 8) accepted issue, 9) Rulereport. (See larger image in appendix F).

Not all of the errors found in this check were relevant, in terms of the energy and indoor climate analysis. One example is the “Wall Intersections” rule being violated and marked as high severity level. When clicking on the rule for this issue, it allowed the author to look into this and locate the specific wall intersection seen in figure 6.8. The program provides details about the construction part involved in the specific issue and provides a Rulereport illustrated as number 9 in figure 6.7, which gives a report of the exact problem, which can be printed to Excel (see figure 6.8). In this case two walls intersect and the Rulereport, provides details on wall types and how much the walls overlap by volume (see appendix E). In this case (see figure 6.8), it seems that two walls are in fact modeled partially on top of each other and this issue would be marked with a red “X” and would be send back to the architect with an illustration and a note saying on with details on the specific type of issue. However, in this particular case the wall issue was not relevant for the energy analysis that this thesis focus on, but it was solved relatively easy in Revit.



Component	Type [mm]	Total Component Volume [m^3]	Intersection Volume [m^3]	Percentage
Wall	Basic Wall:Glass	1.19	0.00	0.28%
Wall	Basic Wall:Exterior 500	139.36	0.39	0.28%
Wall	Basic Wall:Concrete100	34.75	0.04	0.12%
Wall	Basic Wall:Concrete 150	66.58	0.12	0.18%
Wall	Basic Wall:Gypsum95	12.20	0.01	0.04%
Wall	Basic Wall:Pergola 100	5.42	0.00	0.00%

Figure 6.8 – Top: Example of intersecting walls. Bottom: the corresponding Rulereport for these two walls and some others with the same issue.

A more serious problem occurred with the skylight constructions, which in Revit were modeled as an extruded box cut into the roof with integrated skylights on one side. The roof and extruded skylight construction did not combine properly and the skylight family that Rubow had created caused an extra opening at the back of the skylight construction, which would only be visible in the gbXML file and not directly in Revit (see figure 6.9). Therefore this was looked into in Solibri to locate what caused this seemingly unexplainable problem.

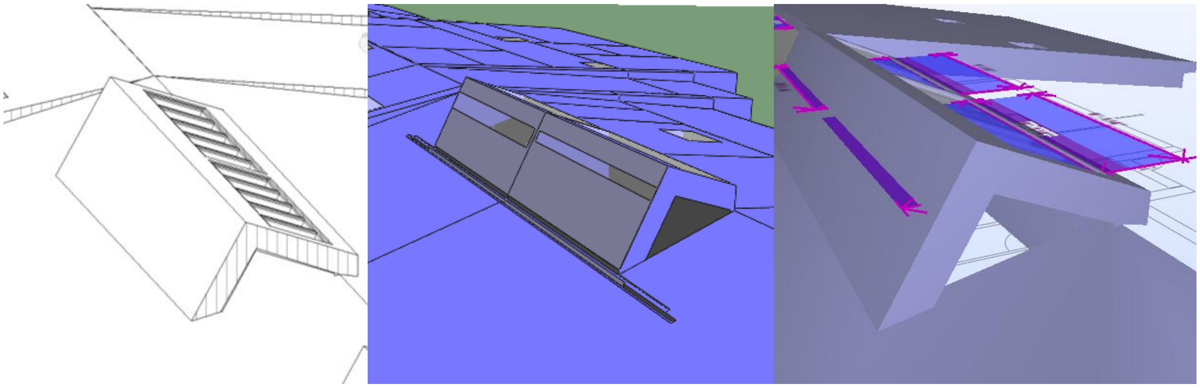


Figure 6.9 - Left: the skylight construction in Revit. Middle: the skylight construction converted to gbXML file. Right: the skylight construction seen in Solibri where the program illustrate that the skylight family are somehow colliding with the skylight construction even though this is not visible in neither Revit nor the IES plug-in.

In figure 6.9 it seems that there are some conflicts with the skylights and the roof construction it is attached to, which might be what causes the problem when converting from rtv file to gbXML file. This picture from Solibri in figure 6.9 has been added to the BCF report as well as an Excel report through the presentation section of Solibri and can be found in appendix E. With the illustration and notes from Solibri, it was much easier to understand the issue and go back to Revit and fix the model. In Revit the skylight family was looked into and modified to a simpler version with less required space around. It was later discovered that this correction alone was not sufficient enough to abolish the issue. Alternatively, the skylight construction had to be modeled larger toward the back, or the extra opening could be deleted manually after import into IES<VE>. The latter option was always available, but the other procedures were tested in case of a future larger project were such manual corrections might be numerous and have to be done by the receiving party. If this issue had to be corrected manually by the receiving party, who does not have proper insights of the model, this could be an obvious source for potentially errors or defects.

As figure 6.8 depicts Solibri found much more issues than what was highlighted in the gbXML report. This has to do with the tolerance/ complexity level set up in the IES plug-in and only some of issues found in Solibri were useful, like the skylight construction. Others did not seem relevant in this case with focus on energy analysis. Those issues that were worth looking into, have been included in an Excel report and used by the author to rectify the model in Revit as explained in the steps in section 6.1.2.1 (See appendix E).

The Information TakeOff (ITO) program section is where specific details of each construction component or type can be located and used for various purposes. A prerequisite for being able to take advantage of the features the ITO section has to offer, is naturally that the user has prior knowledge in the field and e.g. knows the principles behind quantity outlet. In this thesis the ITO was used to generate an example of a building element components list (see appendix E), which can be used by the contractor to determine the material types and quantities to be installed. Another example could be generating of a space list with properties of area, number and so forth, which for instance could be used for preparation of maintenance contract. An example where this was used is in one of the case studies in the [ØG-DDB 2012] research project. In this, the generated space list was used as basis for the preparation of the cleaning contract prior to commissioning, providing much time saving for the cleaning company [ØG-DDB 2012]. This case is one example of one party doing the “extra” piece of work and another party harvesting the benefits this can provide.

6.3 IES<VE>

This section contains prerequisite for use of imported models from Revit, technical specifications of the IES<VE> simulation model and results obtained through simulations.

6.3.1 Adjustments to the model after import

6.3.1.1 Building components

Exchanges of models between different programs is often a question on what is possible to exchange and how. Frequently the user will find that as described in section 6.1 (model transfer from Revit to IES<VE>), a set of precautions have to be made and a specified procedures followed. This is often true in both the sending and receiving software. In this case the Revit model went through a number of modification before exporting as a gbXML file became successful, but there are still a number of issues that has to be adjusted in IES<VE> prior to the actual energy and indoor environment model set up can take place.

In the exchange between Revit and IES<VE> it is important to emphasize that the gbXML file is an “approximated” BIM model, in the sense that it contains information regarding building component properties from the predefined building component database. However, since this list is non-editable it means that e.g. an exterior wall will be imported as this and contain the materials assigned to this, but often this predefined list of components does not contain the exact components you need. As a result the engineer has to construct and assign every building component in IES<VE>. This means that in reality only the geometry and predefined (not correct) information of building component is exchanged. Likewise, there gbXML file contains no information about internal gains; this type of information has to follow the model separately. It could be argued that this is not a direct architectural concern, but if the information is available it would make a significant difference to have it somehow exchanged and attached the model.

In regard to the building components the author sees two possible scenarios which could increase the interoperability and make this a more BIM like exchange scenario. A) The plug-in could understand and use the material properties assigned by the architect in Revit and include it directly in the exchange file. This is much like what the IFC format is capable of and IES<VE> has announced that they are working on this type of exchange [IES BIM 2011]. B) The architect could specify and assemble the building components used in the project directly in the plug-in. This way the correct information would be included in the model, but it would require much extra time used by the architect on something that is not really his field and therefore would most likely have to charge extra for.

6.3.1.2 Simplifications

In the conversion from a rvt file to a gbXML file the model was considerable simplified by the use of the “simple with shading surfaces” complexity level. This is most evident in places where relatively small geometries are joined for the sake of making the exchange and later simulations run smother. However, there is no gain without loss and in this context it means that the window frames are neglected, resulting in changes in the geometry size of the windows. These are minor details, but could prove to be relevant when performing daylight simulations. To compensate for this, the window geometries from the Revit and IES<VE> model have been compared and consequently the Light Transmittance (LT) values of the windows in the latter model have been adjusted. See appendix M for further details.

6.3.1.3 Simulated rooms

The entire modified Revit model has been converted and imported to IES<VE> to test this process, but only a minor portion of these have been selected for simulation. This is due to the fact that many of the rooms in the building is relatively identical, and it requires considerable increase in input and setup time in IES<VE> for e.g. exposure and control profiles and HVAC system specifications for each room included in the simulation. For these two reasons, it is relatively common practice that only a few rooms are being analyzed and the rest of the building is dimensioned based on estimations in relation to the simulated results. This approach involves some precautions in regards to the indoor environment as well as energy simulations which will be discussed later. The selections of rooms are based on their frequency of use, varied internal- and external exposures due to gains and orientation as well as their diversity in room type. The following room types are used for simulation:

- **Common room (CR) 1, 2** and **3**. Located in the southwest corner of the building, these rooms have a high occupancy and solar exposure load. Two of the rooms (CR1 and CR2) are simulated with similar interior loads and are representative for the kindergarten section. This is done to test and make sure to get a reasonable representative, due to varying transmission areas and to see if the model geometry had been imported correct or if it contains issues causes during the model transfer process. If the model contains incorrect geometry it would most likely be visible in the form of deviations in the simulation results. The third common room (CR3) is representative for the nursery section of the building which means that the occupancy load is considerably lower.
- **Main kitchen**. Located in the middle section of the building with a southwest facing façade, this room is mainly in use during mid day, where it is exposed to high internal- and possibly external gains and provides a working location.

- **The office**. Located in the middle section of the building with a northeast facing façade, this room has low internal gains form only one occupant and limited equipment. The rooms' location is illustrated in figure 6.10.

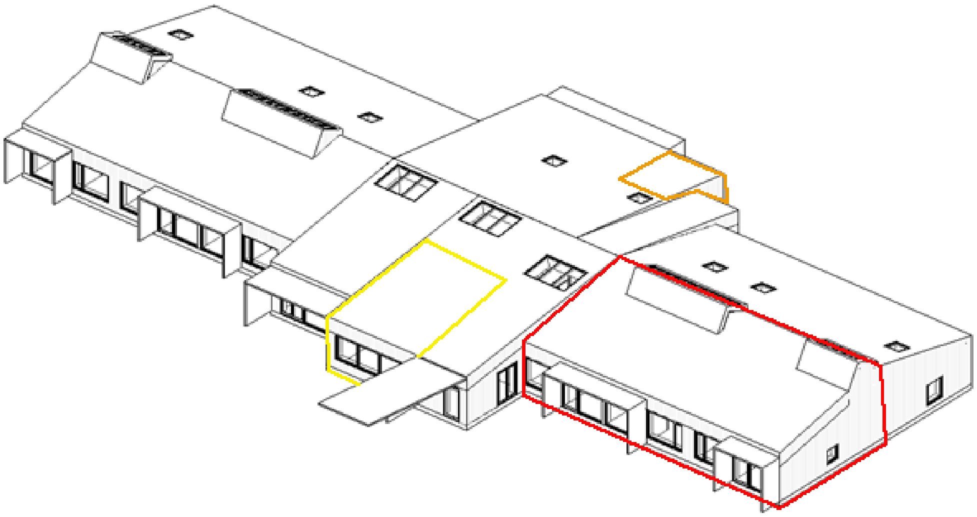


Figure 6.10 - Illustration of the three room types' location (north is up in the illustration). Red: common rooms; yellow: main kitchen and orange: office.

6.3.2 Technical specification of the model

One of the intentions with the thesis is to test and evaluate the process from the architectural drawings/model until finished indoor environment analysis in a dynamic simulation program through the two described approach. Therefore the IES<VE> model has reused the as many inputs possible from the most promising scenario in Bsim (scenario 2). As such, where ever possible, the same technical specifications as in Bsim scenario 2, in terms of building envelope materials, settings for the HVAC system, internal gains, occupant profiles etc. are reused and can be referred to. However, in the section is a brief description of the main settings for the model. The input for the IES<VE> model can be found in appendix M.

6.3.2.1 Site and climate data

The location set in the climate database is set to be Copenhagen which is 55.4 north and 12.3 east. IES<VE> uses a ground reflectance of 0.2 as standard and the terrain type is set to be suburb. The Climate database is the Danish Design Reference Year (DRY).

6.3.2.2 Building operations

Energy used for pumps, fans, pipes, filters etc. are not investigated in detail in this thesis which means that the standard IES<VE> inputs has been used.

6.3.2.3 Building envelope

Building envelope properties are similar the description in section 2.8.1.4 and is shortly presented in table 6.1.

Table 6.1 - Building envelope properties.

Building envelope	U-value total [W/(m^2*K)]	U-value center [W/(m^2*K)]	g-value [-]	LT [-]
Roof:	0.1	-	-	-
Facade:	0.1	-	-	-
Windows:	0.95	0.9	0.57	0.73
Skylights:	1.2	1.1	0.43	0.71
Ground slab:	0.1	-	-	-

6.3.2.4 Domestic How Water

The energy used for Domestic Hot Water (DHW) is assumed to be the standard 100 l/m^2 according to [SBi 213]. The value of 100 l/m^2 is the standard input in Be10 and therefore also used in this context. However, in reality the DHW consumption might only be ~40-70% of this because the standard value is based on a dwelling where showering is accounted for, which is not very relevant in this type of building.

With the standard input, the energy consumption for DHW of is calculated by:

$$\text{Energy DHW} = \frac{V_{DHW} * \rho_{water} * C_{water} * \Delta T}{\frac{kJ}{kWh}}$$

$$\text{Energy DHW} = \frac{100\,\frac{\text{l}}{m^2} * 1\,\frac{kg}{l} * 4.186\,\frac{kJ}{kg * K} * 45\ K}{3.6 * 10^3\,\frac{kJ}{kWh}} = 5.23\ \frac{kWh}{m^2}\ pr.year$$

Where:

ρ_{water}: the density of water ($1\,\frac{kg}{l}$)

C_{water}: the specific heat capacity of water ($4.187\,\frac{kJ}{kg*K}$)

ΔT: the assumed temperature difference between water delivered before and after heating by water from the district heating network (55°C – 10°C).

The energy used for the DHW is used in the energy calculation for the building later.

6.3.2.5 Internal gains

The internal gains vary depending on the room type and size, but consist of the occupants and electrical lighting in the common rooms. On top of this the office has gains from computer equipment and the kitchen has gains from all common kitchen equipment which can be seen on a list in appendix M.

6.3.2.5.1 Occupant profiles

The user profiles in Tranehavevej are used to estimate the number of occupants at any given time in each of the three simulated rooms. The total expected number of occupants in the daycare institution is approx. 102 children (22*3 + 12*3) and 20 adults. The common rooms have the exact same profile as in table 5.11 and 5.12 in the Bsim section. The kitchen and office occupant profiles are as illustrated in table 6.2.

Table 6.2 - Occupant profiles office and kitchen.

	Occupants	Time profile		
Office	1	9a.m.-10a.m.: 60%	10a.m.-2p.m.: 80%	2p.m.-4p.m.: 60%
Kitchen	2	10a.m.-3p.m.: 80%		

The occupant in the office is expected to have a sensible load of 70 W and latent load of 50 W according to the expected activity level and cross reference to ASHRAE standard. In the kitchen these values are multiplied with 120% (educated guess) to take the expected higher metabolic rate into considerations. The two kindergarten common rooms share inputs with the Bsim model which takes the mix of children and adults into consideration. In the nursery common room there are only 12 children (refer to 22 in the kindergarten rooms) and the children are smaller, so the average loads are reduced by 20% by following the same calculation procedure for heat production as in section 5.5.1.1 (Bsim occupant load) and [sundhedsguiden].

6.3.2.5.2 Artificial lighting

The general lighting level is 200 lux in the common rooms (as requested by Esbensen) and 300 lux and 500 lux is used in the kitchen and office respectable in accordance with the DS-EN 15251 standard. These values are sustained through a combination of daylight and artificial lighting to ensure that only a minimum amount of electricity is used for lighting while maintaining a proper lighting level. A dimming profile ensures that the lighting control lowers the artificial lighting intensity in accordance with the amount of available daylight in each room, determined through a daylight calculation in the Radiance application in IES<VE>.

6.3.2.6 Ventilation strategy and HVAC

The ventilation strategy is set as similar to the strategy from scenario 2 in Bsim as possible, but the difference in operation systems in the two programs causes minor differences to the results. These operation differences are for instance in the way in which the ventilation system reacts to CO_2 concentration. In Bsim the set point for CO_2 is fixed at 900 ppm. and in IES<VE> this ventilation is set to activate at 600 ppm. with a steady increase until full load at 900 ppm. A second example is the fact that exterior temperature can be included in the ventilation control in IES<VE> and not in Bsim.

The infiltration and natural ventilation is activated through the program's ApacheSim application and the HVAC is applied through the ApacheHVAC application.

6.3.2.6.1 Infiltration

Same as in Bsim, all rooms has an expected infiltration rate of 0.06 h^{-1} all year around.

6.3.2.6.2 Natural ventilation

The naturally ventilation is manually operated and can therefore only be activated during the open hours (7 a.m. – 5 p.m.) of weekdays. The natural ventilation is controlled in the program by the interior temperature and the CO_2 concentration in each room as depicted in table 6.3. During summer the activation set point is lower than the rest of the year in order to address the expected higher temperatures before this can become a problem. This way energy for the HVAC system is saved by delaying activation of this until situations where the natural ventilation is not sufficient. The air change by natural ventilation is again $2h^{-1}$ [THV1] and the strategy is very similar to scenario 2 from Bsim the main difference is due to the two programs different operation methods.

Table 6.3 - Natural ventilation strategy.

Natural ventilation (only in use during occupied hours, manually operated)		
Ventilation strategy	Set points	
Summer - occupied (Jun. - Aug.)	Ventilation activated	Full ventilation load
CO_2 concentration [ppm.]	600	900
Air temperature [°C]	20	22
Rest of year - occupied		
CO_2 concentration [ppm.]	600	900
Air temperature [°C]	24	26

A minimum temperature of 10°C is expected before the natural ventilation is activated.

Activation of the natural ventilation in use during a summer day in the common room in the Southwest corner of the building is illustrated in figure 6.11.

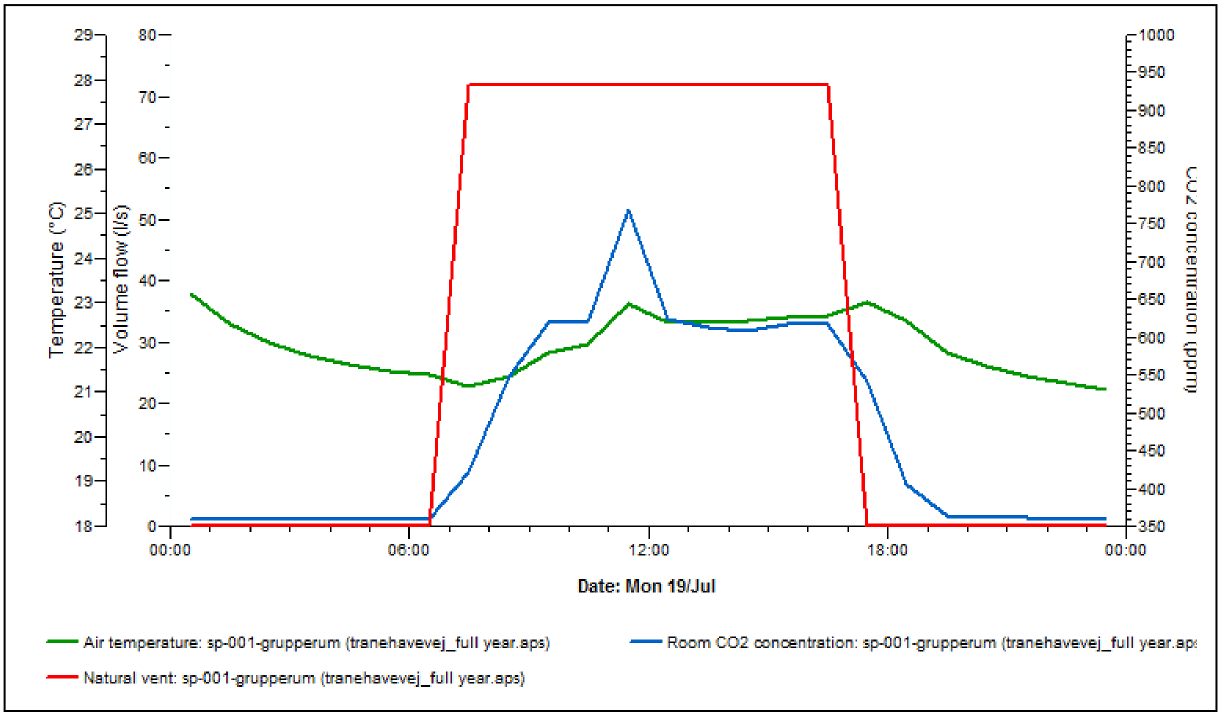


Figure 6.11 - Illustration of the relation between the natural ventilation (red), indoor air temperature (green) and CO_2 concentration (blue) on a summer day in a kindergarten common room.

Outside the summer months the natural ventilation is only occasionally activated when the set point in table 6.3 is reached and the exterior temperature is above 10°C.

6.3.2.6.3 Mechanical ventilation

Similar to the natural ventilation, the mechanical ventilation system is also controlled by the interior air temperature and the CO_2 concentration by a sensor in each room with operation as depicted in table 6.4.

Table 6.4 - Mechanical ventilation strategy.

Ventilation strategy	Activation set points	
Occupied (7a.m.-5p.m.)	Ventilation set point	Full ventilation load
CO_2 concentration [ppm.]	600	900
Air temperature [°C]	22	24
Unoccupied (5p.m.-7a.m.)		
CO_2 concentration [ppm.]	1200	1300
Air temperature [°C]	20	22
Weekend		
CO_2 concentration [ppm.]	-	-
Air temperature [°C]	25	27

The corresponding radiant floor heating set points are 22°C and 19°C during day and night respectively.

When the ventilation set point is reached, the mechanical ventilation activates and increases the air change rate if the temperature continues to rise until the maximum of $3h^{-1}$. The system is set to have a heat recovery of 85% from the exhaust air to preheat the inlet air at times where this is necessary. The supply temperature is dependent on the exterior air temperature so the inlet air temperature is preheated/ cooled accordingly to the exterior temperature. The setup of the HVAC system is seen in figure 6.12.

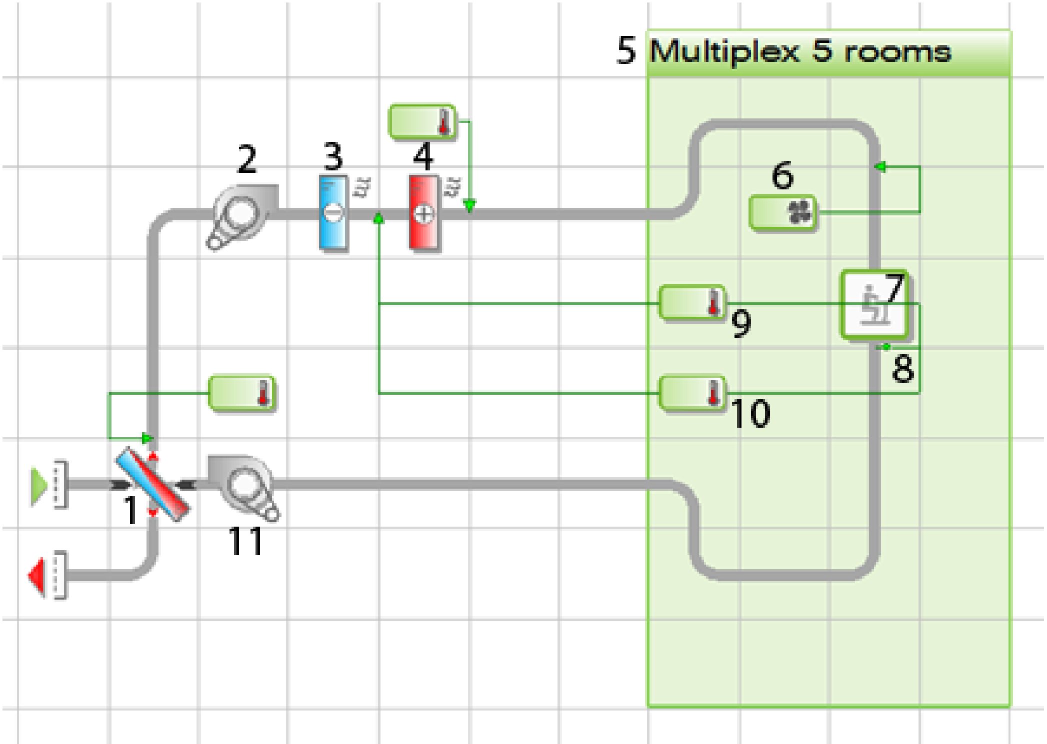


Figure 6.12 - Principle diagram for the HVAC system.

1) Heat recovery unit – 85% heat recovery from the exhaust air when the exterior temperature is below 20°C.
2) Main supply fan for all five rooms attached to the HVAC system.
3) Cooling coil receives feedback from the exhaust temperature sensors in each room and activates if temperatures exceed the set point values.
4) Heating coil activated in when exterior temperature falls below 20°C.
5) Multiplex illustration encompasses all five simulated room into the one illustrated for ease of setup and adjustments.
6) Individual ventilation fan for each room with the following set points/full load values: day: 22°C / 24°C; night: 20°C / 22°C; weekend: 25°C / 27°C.
7) Illustration of the five simulated rooms, which may be adjusted as a unit or separately.
8) Location of the exhaust temperature sensor for cooling.

9) Day temperature sensor (7a.m. – 5p.m.) providing feedback to the cooling coil according to following set point/full load values: 24°C / 26°C; minimum inlet temperature: 18°C.
10) Night temperature sensor (5p.m.-7a.m.) providing feedback to the cooling coil according the following set point/full load values: 22°C / 24°C; minimum inlet temperature: 18°C.
11) Exhaust ventilation fan.

*The VAV ventilation strategy are also dependent on the CO_2 concentrations as depicted in table 6.4 and has a maximum air change of $3h^{-1}$ in all five room types.

Example of the operation of the mechanical ventilation is seen in figure 6.13:

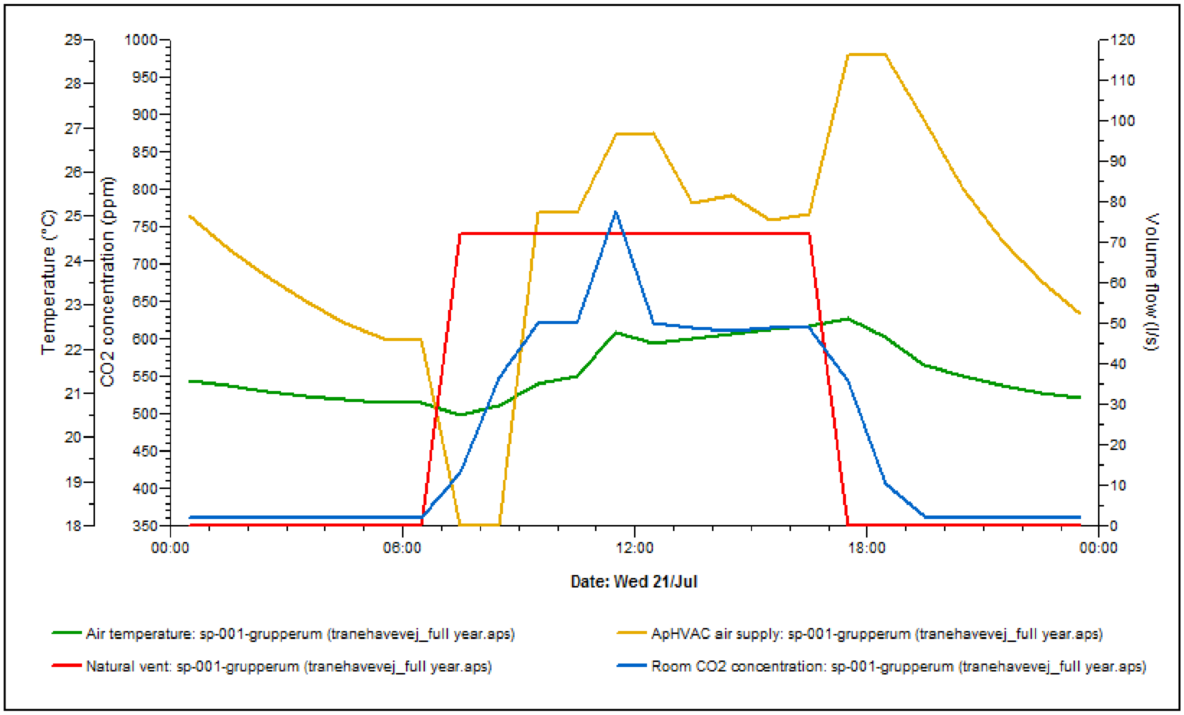


Figure 6.13 - Relation between the air temperature (green), CO_2 concentration (blue), mechanical- (yellow) and natural ventilation (red) on a summer day. The peak of mechanical ventilation is around 6 p.m. is due to the change in set points from 22°C during day and 20°C during night.

In figure 6.13 it is seen how the natural ventilation is activated when the occupants arrive in the morning and because the air temperature raises the mechanical ventilation starts up again, after having been off for short period in the morning. During the middle of the day when the occupant density is expected to be highest around lunch, it is seen how the temperature and the CO_2 concentration has a simultaneous peak point which causes the mechanical ventilation to increase its air change rate.

6.3.2.7 Radiant floor heating

Similar to the Bsim setup the heating of the building is performed through a radiant floor heating system active between the middle of September till end of April. Since the heating supply is from the district heating network the utilization rate of this is set to 100%. Again here the supply temperature is dependent on the exterior temperature with operation set point temperatures of 22°C and 19°C during day and night respectively. The inputs for the radiant floor heating are seen in table 6.5.

Table 6.5 - Parameters of the radiant floor heating system activated through the ApacheHVAC system.

Parameters for radiant floor	Floor slabs	Source: calculation or assumption
Orientation	Horizontal	-
Radiant fraction	1	Heat transfer by radiation only
Reference temperature difference [K]	5	Assumption
Heating output at Δt_{ref} [W/m^2]	40	Assumption
Maximum input from heating [kW]	20	Due to district heating the supply is assumed to be unlimited
Distribution pump consumption [kW]	0	Pumps are not applied
Material	Aluminum	Best available option
Total weight of tubing incl. water [kg/m^2]	1.2	The tubes are assumed to have 20 cm distance between them
Water capacity [l/m^2]	0.7	Total weight of tubing incl. water

The peak heating consumption is during the morning hours on the 9th of February with 47.3 W/m^2.

6.3.2.8 Cooling

As seen in the HVAC principle diagram in figure 6.12, there is an exhaust air temperature sensor connected to the cooling coil, which activates this according to table 6.6 and cools the temperature of the inlet air. Cooling is only provided to the in the common rooms and not the main kitchen nor the office.

Table 6.6 - Cooling set points.

Cooling	Activation set point [°C]	Full load set point [°C]	Minimum cooling inlet temp. [°C]
Occupied (7a.m.-5p.m.)	24	26	18
Unoccupied (5p.m.-7a.m.) + plus weekend	22	24	18

The peak chiller energy consumption is during the afternoon on the 6th of July with 39.0 W/m^2.

6.3.2.9 PV panels

The 25 m^2 solar panels were calculated to be necessary through the original Be10 calculation, to ensure that the building fulfills BR15 energy requirements and are installed on the roof of the southwest facing middle section of the building. In the original Be10 calculation the 25 m^2 solar cells are added to the entire building. In this simulation of five representative rooms the same PV panel area is applied but their energy output has been multiplied with a factor of 0.2 in the total energy consumption calculation to adjust for the fact that the simulation only represents 20% of the building. The PV panels are meant to be aligned to the top of the roof in order to make them blend into the architecture of the building as much as possible. The specifications of these are the same as in the Bsim model, determined by a specialist at Esbensen and can be found in appendix G.

6.4 Results of IES<VE>

6.4.1 Energy consumption

The energy consumption of the building is calculated on the basis of the five representative rooms included in the IES<VE> simulation. These rooms are the same as specified in the previous section. All together these five rooms comprise 195 m^2 gross area of the total 977 m^2 gross area (~20%). Due to their diversity in terms of expected internal load, occupant user pattern, expected energy consumption and orientation they are assumed to be reasonable representation of the total conditioned and frequently used areas in the daycare institution. However, there are rooms that due to their user pattern and room type requires considerably less or no room conditioning, heating or lighting. These rooms are listed below with a description in brackets next to the room type describing, which of the three categories they are expected to consume less than the five representative rooms.

- **Storage facilities** (no heating, no air conditioning and seldom used lighting)
- **Boiler room** (no additional heating necessary, no air conditioning and seldom used lighting)
- **Staff wardrobe/ print room** (only limited use of air conditioning and lighting)
- **Staff toilet** (only exhaust ventilation and limited use of lighting)
- **Laundry/ cleaning room** (only exhaust ventilation and limited use of lighting)
- **Toilets** (only exhaust ventilation)

If this consideration is taken into account, it would be possible to use this information and room areas to calculate a weighted partial factor to be multiply on each category of the energy consumption and thereby reduce the total energy consumption per square meter. This would give a more accurate picture of the actual energy demand of the entire building and make the IES<VE> energy consumption result more comparable, to the result obtained through the original Be10 calculation, because this does include the entire building. However, a weighted partial factor like this will easily be inaccurate and subject to a matter of opinion. Therefore in this thesis the consideration is only brought to the reader’s attention but not used in the energy consumption calculation.

Another factor worth mentioning which could potentially cause a minor deviation between the result from the Be10 energy consumption and the one calculated in IES<VE> is the fact that the five representative rooms all together have a lower transmission area to heated floor area ratio than the entire building does. This difference is mainly due to the four of the five representative rooms having no gable wall area. However, since the façades are relatively well insulated with a U-value of 0.1 W/(m^2*K), this detail is also neglected in this context.

Since the building is designed to fulfill energy consumption requirements of BR15 the COP-factor on the cooling coil in the ventilation system is assumed to be relatively high at 4.0 [powerknot]. According to the building code the energy consumption for electricity is to be multiplied by a factor 2.5, and according to the BR15 building code the energy consumption for district heating may be multiplied by a factor of 0.8 [BR10]. The calculated energy performance of Tranehavevej divided into separate categories is depicted in table 6.7.

Table 6.7 – The energy performance of Tranehavevej calculated in IES<VE>.

Energy service (simulated area: 195 m^2, COP: 4)	Energy [kWh pr. year]	Energy/area [kWh/m^2 pr. year]	Primary energy factor [-]
Cooling	303	2.3	2.5
Total lights energy	1150	5.9	2.5
ApHVAC distribution fans.	1605	8.2	2.5
Heating	5562	28.5	0.8
DHW	1020	5.2	1
PV. Panels	-504	-2.6	2.5
Energy performance BR15 [kWh/m^2 pr. year]			**62.7**
Energy performance BR10 [kWh/m^2 pr. year]	(no primary energy factor on district heating)		68.4

Cooling is only provided to the common rooms so the energy consumption here shall only be divided by 132m^2. The results from the PV panels are from the entire 25m^2, so this needs to be distributed out on the entire building. The calculated energy consumption in table 6.7 should be considered as a good indication of the institution's energy consumption but not the ultimate truth because the controls in the programs are very complex and could possibly be trimmed even better than the case here and thereby reduce the energy consumption an estimated few percent. (See calculation of energy consumption in appendix M (IES-VE)).

The calculated energy performance from IES<VE> in bold numbers is significantly higher than the energy consumption in the original Be10 calculation (see table 6.8). In this context it should be emphasized that the original Be10 calculation was made for authority approval during the conceptual design phase prior to any dynamic simulations. This means that the original Be10 did not include mechanical cooling as well as the ventilation rates in the original Be10 calculation were too low, both of these parameters have been changed after the dynamic simulations in Bsim and IES<VE>. Additionally, the original Be10 calculation is based on an exterior design temperature of -12°C and an interior operative temperature of 20°C. To be able to compare the results from Be10 and IES<VE> another Be10 tailored calculation has been made. In the Be10 tailored calculation the ventilation rates, internal loads and other minor adjustments have been made to fit the results of necessary ventilation rates and the more accurate input obtained in IES<VE> (see details in appendix M). In the Be10 tailored calculation mechanical cooling has been added to the common rooms (27% of the total building area) with the estimated COP-factor of 4 and the design interior temperature is set to 22°C. The energy consumption results from the two Be10 calculations and the IES <VE> simulation are depicted in table 6.8.

Table 6.8 - Comparison of energy consumptions calculated in Be10 and IES<VE>.

	Interior design temperature day/night [°C]	Energy consumption [kWh/m^2 pr. year]	Relative energy consumption compared BR15 requirements [%]
BR10 energy frame	20	74.3*	
BR15 energy frame	20	43.3*	
Energy consumptions (BR15 values)			
Original Be10 (authority approval)	20	42.5	98
IES<VE> simulated	22/19	62.7	145
Tailored Be10 (to results from IES<VE>)	22	49.6	115

** Incl. 1.3 kWh/m^2 supplement for extended operation hours above 45h/week [SBi 213].If the interior temperature is set for 20°C in the Tailored Be10 calculation the energy consumption is only 44.5 kWh/m^2 pr. year, which is only 2 kWh/m^2 pr. year and 1.2 kWh/m^2 pr. year above the Original Be10 and BR15 requirements respectively.*

It is seen in table 6.8 that the energy consumption calculated in IES<VE> is higher than both the original and tailored Be10 calculation. In section 2.5 the three studies [Alilou, et al., 2011], [Petersen, 2012], [Dethlefesen, et al., 2012] and the statement from Co-developer of Be10 Søren Aggerholm all came to the same conclusion that Be10 tends to calculate a lower energy consumption than the actual or the one calculated in a more advanced building simulation program. Keeping this in mind, along with the precautions stated previously due to only five representative rooms being included in the IES<VE> model, the actual energy consumption of the building, when it is built and taken into use, will likely be somewhere in between the two result of the tailored Be10 and the IES<VE> calculation.

6.4.2 Indoor environment

6.4.2.1 Thermal indoor climate

The thermal indoor climate is evaluated on the temperatures in the open hours of the year being within the boundaries of the comfort zone. The amount of overheating hours in each of the simulated rooms during this period is depicted in figure 6.14.

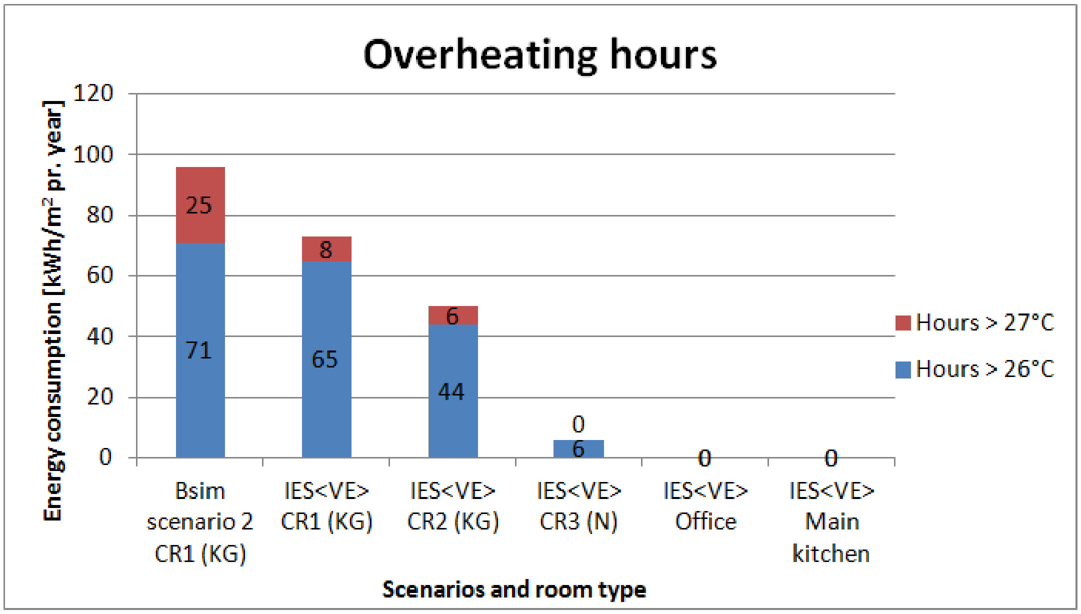


Figure 6.14 – Overheating hours from simulations in Bsim and IES<VE> during weekday between 7a.m. – 5p.m. (CR: Common Rooms; KG: Kindergarten; N: Nursery).

It is seen in figure 6.14 that despite the results large deviations, all rooms fulfills the thermal indoor requirements in the building code. In the office and kitchen there are no overheating hours, even without cooling applied, because these two rooms are subject to relatively limited occupant loads and only during a certain part of the day. In the case of the office its orientation toward the northeast and limited equipment load also limits its solar exposure and as a result there are no overheating hours. In the kitchen there is one hour where the temperature drops just below 20°C, this is the only one of the simulated rooms with temperatures below this limit. Since it is only one hour and the kitchen is only in use during the middle of the day this is regarded as acceptable.

In terms of the overheating hours in common room 1 (CR1) figure 6.14 shows, that there is a significant difference between the Bsim scenario 2 results and the IES<VE> results for CR1. Some of this may be explained by the small differences in the control of the two programs ventilation even with the same set point temperatures, which makes them complicated to streamline completely. An example of this was given previously with the natural and mechanical ventilation in Bsim set to react on a more fixed set point than in IES<VE>. Another minor factor that can have affected the results is the fact that the Bsim model has no extruded skylight construction as the IES<VE> model has. This means that the Bsim model has a slightly smaller roof area than the same room in the IES<VE> model.

Comparing the overheating hours in IES<VE> from CR1 and CR2 there seems to be a considerable deviation between these as well. These two rooms are similar in all aspects except CR1 is located at the southern corner of the building, and therefore has a considerable gable transmission and solar exposure area toward south/southeast that CR2 does not have. The reason why both of these rooms are included in the simulation was to check if the odd looking geometry around the skylights created as a result of the import process from Revit would affect the simulated results. If this had been the case and this oddly looking geometry had in fact been holes in the roof, it is assumed that the results would have had considerably larger deviations in hours outside the thermal comfort zone of 20°C - 26°C. Therefore the deviation is assumed to be caused mainly by the difference in transmission areas between the two rooms. In the nursery room (CR3) the occupant load is approx. 80% the occupant loads in the other two common rooms but the same ventilation and cooling is available. This could explain why there are almost no hours outside the thermal comfort zone in CR3.

Taking a look at the thermal indoor climate in a single day example in the nursery common room during a summer day illustrated in figure 6.15, it is seen that the ventilation rate reduces around 7 a.m. at the start of the day. This marks the change from the night set point temperature at 20°C and the day set point temperature of 22°C. This is also the reason for the raise in ventilation rate at the end of the day at 6 p.m. The temperature can be seen to be lain in the range of 20°C-22°C the entire day. The internal heat gain graph in figure 6.15 has a peak point around lunch time at 12 p.m. this results in a peak in CO_2 concentration and ultimately in ventilation rate which is determined upon temperature and CO_2 concentrations. (More similar examples from the other simulated rooms can be seen in appendix M).

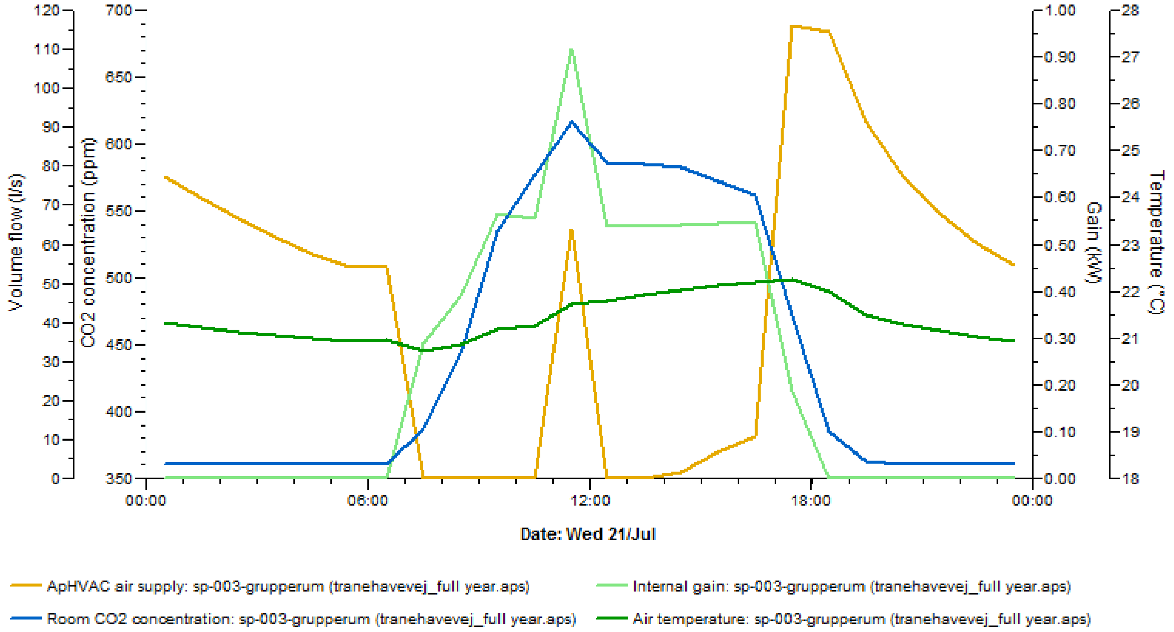


Figure 6.15 - Example of relation between indoor temperature, internal gains, CO_2 concentrations and ventilation during one summer day in the nursery common room.

6.4.2.2 Atmospheric indoor climate

The atmospheric indoor climate quality is assessed on the maximum CO_2 concentrations in the five representative rooms and compared to the results from Bsim scenario 2 in table 6.9. It is seen that the CR1 and CR2 in IES<VE> shows CO_2 concentration values approximating limit of 1000 ppm., but no hours above this limit (see more in appendix M).

Table 6.9 - Number of hours during one year where the CO_2 concentration approximates the 1000 ppm. limit. in the simulated rooms.

CO_2 concentrations			
Scenario and room	Hours > 960 ppm.	Hours > 1000 ppm.	~max ppm.
Bsim scenario 2 CR1 (KG)	223	81	1060
IES<VE> CR1 (KG)	659	0	990
IES<VE> CR2 (KG)	659	0	990
IES<VE> CR3 (N)	0	0	670
IES<VE> Office	0	0	590
IES<VE> Main kitchen	0	0	450

(CR: Common Room; KG:Kindergarten; N: Nursery)

Comparing the number of hours approximation the CO_2 concentration limit from Bsim scenario 2 and IES<VE> CR1, it is seen that the Bsim scenario has approx. 1/3 as many hours above 960 ppm. as CR1 in IES<VE> but it seems that the ventilation in IES<VE> is better at avoiding going over the edge of 1000 ppm. The lower three rooms in table 6.9, has the same air change rates at the top three rooms and does not come near the CO_2 concentration limit, because the occupant load in these rooms are considerably lower. Overall the air quality in all the rooms are considered to be acceptable and within the comfort zone for a large majority of the occupied time of the year. So the determined air change rates of $3h^{-1}$ mechanical ventilation plus $2h^{-1}$ natural ventilation during the summer seems to be sufficient.

In the example from CR1 in figure 6.16 the CO_2 concentrations during a period of 14 days in January dipicted. Because most of the occupants are expected to be inside the majority of the day during this time of year, this is assessed to be the peek period of CO_2 concentration in the common rooms (see more in appedix M).

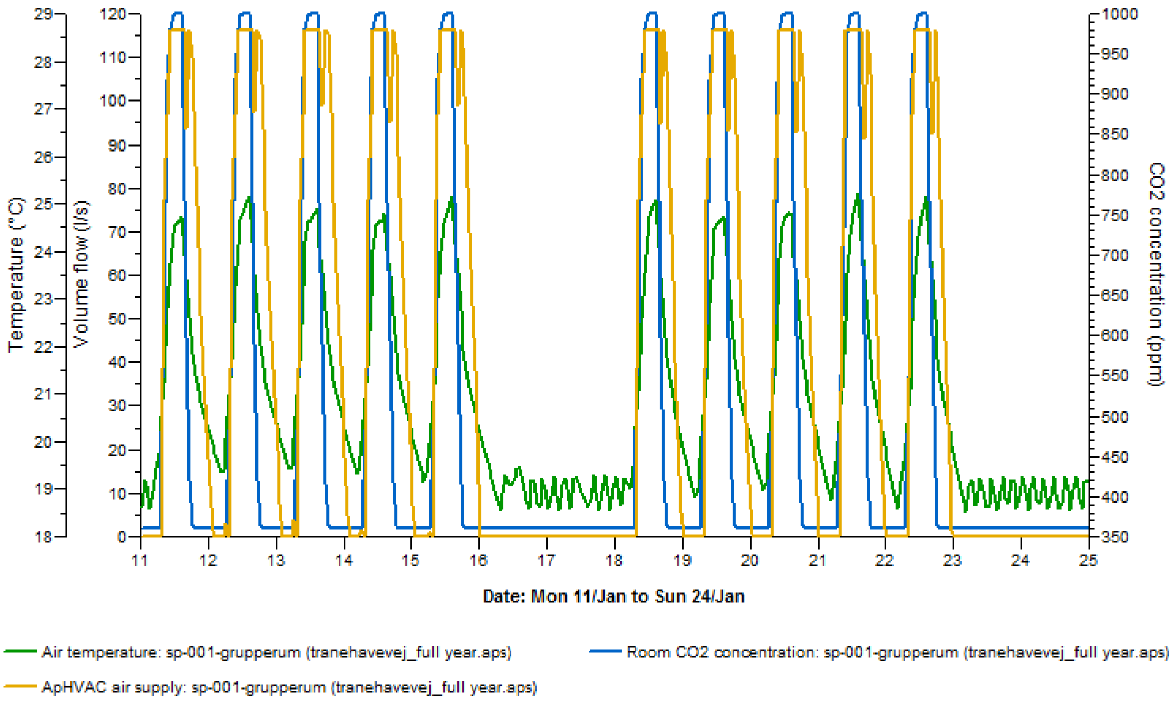


Figure 6.16 - Illustration of the CO_2 concentration in CR1 during 14 days in January.

Figure 6.16 shows that the air temperature is kept at approx. 19°C during the weekend and quickly raises when the occupants arive in the morning. It is seen that the air supply graph in figure 6.16 is a dirict result of the raise in temperature and CO_2 concentration and both the air change and CO_2 concentration graphs realitively quickly reaches their peak values of $3h^{-1}$ and just under 1000 ppm. respectively. When there are no occupants present for a longer period of time, the ventilaiton system ensures that the temperature and the CO_2 concentration is decreased to their ideal non occupied time values 19°C and 350 ppm. respectively.

7 Discussion

7.1 The case study

7.1.1 Energy

The stated goal of the project in regards to the energy consumption was to fulfill the requirements of BR15. According the energy consumption results in figure 6.7 and 6.8 it was not possible to reduce the energy consumption of neither the IES <VE> simulation nor the tailored Be10 calculation enough to fulfill the BR15 energy requirements. However, if the set point interior temperature in the tailored Be10 calculation is set for 20°C the resulting energy consumption is 44.5 kWh/m^2 pr. year (as opposed to 49.6 kWh/m^2 pr. year), thus only 1.2 kWh/m^2 pr. year than the requirement. This indicates how much effect just 2°C has on the energy frame and it will be illustrated how much this means to the amount of supplied energy/ renewable energy production.

At this point in the late project proposal / early preliminary design phase it is too late to make any major passive design changes to the building, this should have been incorporated during the conceptual design phase. If so, these passive design changes could have included incorporation of natural night ventilation as the simulation has shown a relatively high demand for ventilation to cool down the common rooms during summer nights, or alternatively reorientation of the most exposed rooms (common rooms). If the common rooms had been orientated toward another direction than southwest the cooling demand would most likely have been significantly reduced or eliminated. However, orientation of the common rooms were decided back in the building program by stating that these need have direct access and visibility to the outdoor playground located in the southwest end of the property, opposite side of the road on the northeastern side of the property [Rubow1].

Another option, which is no longer available at this stage, could have been to reduce the transmission areas by having two stories as opposed to just one, same as the institution on Baunehøj Allé which share contract and design team with Tranehavevej project. Concerns regarding transmission areas were raised at a relatively early stage when Esbensen were first involved in the case, but since the overall geometry had already been determined at that point, this was not an available option either. The fact that the entire design team was not involved from the beginning of the project makes it a less than ideal integrated design process. At this stage the design team is left with options of renewable energy sources in order to be partially energy self-sufficient and thereby reduce their demand for supplied energy. Renewable energy was already incorporated in the form of PV panels during the conceptual design phase, but it seems now that with increased ventilation rates, incorporation of cooling and raising the operative temperature form 20°C to 22°C this causes an increased heating demand and the original 25m^2 PV panel are no longer sufficient. One option to reduce the demand of supplied energy could be to increase PV panel area, incorporate a heat pump or solar thermal panels to reduce external energy demand for preheat of domestic hot water. If the client decides to go on with a solution with increased PV panel area to fulfill the BR15 requirements, the following PV panel areas are necessary depending on the aimed operative temperature:

Table 7.1 - Relation between necessary PV panel area in the original and tailored Be10 calculation and their corresponding operative temperature in order to fulfill BR15 energy requirements.

	Operative temperature 20°C	Operative temperature 22°C	Total energy consumption at 20°C/22°C [kWh/m^2 pr. year]*
Original Be10 PV panel area [m^2]	25	46	42.5 / 42.6
Be10 tailored PV panel area [m^2]	32	50	42.5 / 42.5

**The corresponding energy consumptions are illustrated together with the PV pane areas because it is chosen not to go directly to the limit of the energy frame (43.3 kWh/m^2 pr. year), but rather a little bit below this in order to be on the safe side of the frame.*

If the Be10 calculation is primarily used for authority approval than the standard set point temperature is 20°C. In this case the tailored Be10 calculation indicates an increase of only 7m^2 PV panel area compared to the original Be10 calculation, in order to fulfill the energy requirements in BR15.

7.1.2 Indoor climate

The dynamic simulations in as well Bsim and IES<VE> indicated cooling a demand to keep the interior temperatures at an acceptable level during the summer months. When cooling is applied in combination with a ventilation strategy that reduces the set point temperature during night and benefit from lower exterior temperatures in this period the resulting thermal indoor climate is very comfortable. Comparing the initial hand calculations from section 5.3 (Requirements for comfort ventilation) the necessary air change rate in regards to the atmospheric indoor climate at 5.1h^{-1}, ended up being confirm as the determining air change rate in the dynamic simulation which had 5h^{-1} for mechanical and natural ventilation combined.

7.1.3 Daylight

Within the given boundaries of the case's design there was not much room for improvements of daylight conditions in any of the three room types included in the daylight simulation (common room, kitchen and office). Especially in the common room a number of investigations have been conducted to increase the portion of the room area with a daylight factor of at least 2%. However, with the room geometry, façade windows and skylight sizes and locations predetermined the investigation was merely a test of window properties to ensure some daylight and reduce heat exposure from solar radiation through the skylight. These are sometimes the terms in a given project, but if the author had the change to influence the design more to optimize the daylight conditions, he would have preferred to go with the second design proposal in appendix H. This solution split the skylight area and places 1/3 of the total ~3m^2

skylight glazing area aligned with the rest of the roof in the opposite corner of the skylight construction.

7.2 Model transfer

The building analysis software IES<VE> used for investigation in this thesis supports model exchanges of a number of different formats such as IFC, gbXML and dxf from an abundance of modeling programs. However, this does not guarantee model exchanges between modeling and building analysis programs can be expected to be flawless. As the two types of programs (design and analysis) are developed for different purposes and the users of these often will have conflicting interests regarding capabilities of particular building models, it is essential for these two parties to communicate their model requirements to one another. As described previously, this can be alleviated through establishment and use of the correct IDM and MVD(s) to eliminate transferring problems such as those experienced during the preparation of this thesis. The applied IDM should include clear definitions regarding modeling of all shared models e.g. in the form of the modeling and exchange guidelines provided by IES for Revit models. Likewise, with an exchange going the reverse direction the architect is responsible for letting the building service engineer or any other partner, know how the shared model needs to be defined in order for it to be understood by the design software.

It goes without saying that, if partner A is requested to make adjustments or perform extra work for the sake of saving time for partner B this can be reason for dispute and conflict. Often one party has to do the necessary work to enable information transfer in order for another party to harvest the benefits of this. An architect may be requested to model according to specific demands to accommodate the demands of the building service engineer and another set of demands from the structural engineer. This can easily involve extra time used without benefitting the architect directly probably causing him to consider whether it is worth investing time in from his point of view. This is exactly the reason why BIM seeks to reach a high level of collaboration, so that one party may not be disinclined to acquiesce to requests from other parties in a project. However, the delivering party needs to be assured that it is not exclusively the receiving party that benefits from this extra work. This can be done through incorporating this strategy into the project IDM so that all parties knows what they are expected to deliver at which time and ensuring that if the project goals are achieved and delivery happens according to schedule all parties share project benefits.

Concerning the lack of information exported in the gbXML file through the IES plug-in the author recognizes the following potential of improvements to increase the interoperability:

1) As the plug-in already can access differences between e.g. exterior- and interior walls in the Revit model it would be beneficial to take this feature one step further. By incorporating a function in the IES plug-in for Revit which through a cross reference to the material library in the Revit model would be able to access which of the materials

from the library are used in the model. This information would preferably be transferred with the model geometry as assigned attributes to the building components ready for the building service engineer to use for analysis. Alternatively, the information from the Revit library could be generated as an attached list of updated building components possibly with comments from the architect ready for the building service engineer to design the corresponding building components in IES<VE>. Since the building component information is already assigned in Revit this cross reference to the material library would only involve alterations to the plug-in. This suggestion would not cause extra modeling time for the architect (provided that the materials are assigned correct) and it would provide the building service engineer with a building model containing more information. This issue demands utilization of another file format than the reasonably simple gbXML format, because this cannot contain information of neither thermal capacity nor internal loads etc. [IES BIM 2011]. With incorporation of the IFC format into the transfer plug-in the opportunities in this regard would be more.

2) During the model transfer from Revit it was experienced that after import in IES<VE> the modifications options was very limited. The user may add or delete an entire room or modify a building component attribute such as window or door, but alterations on the geometry by e.g. adjusting the width of the skylight construction to test the effect of increased skylight area was not possible. This feature is regarded as potentially significant, because it allows the user to make alterations in IES<VE> for different analysis without having to re-import and therefore re-assign all building materials, user profiles etc. It should be mentioned that this issue is only relevant in imported models, as models created in the IES<VE> ModelIT application are subject to fewer restrictions. However, in this regard the fact that the IES plug-in only supports one way transfer, any modifications would have to be compared with a new imported geometry and the program will indicate any inconsistencies between the two models. Alternatively the architectural Revit model and the modified IES<VE> could be exported as IFC to Solibri and checked for inconsistencies there. In any case it would be preferable with the ability to do more modifications.

3) In relation to model clean up and correcting geometry problems assessed through the IES Report in the IES plug-in it would be very beneficial to have more information than just the type of issue along with the building component and surface/intersection of question provided. If the report could provide information on the exact location of the issue and possibly include an illustration it would be much easier to locate and correct this in the Revit model. Since the IES Report does not provide this level of detailed information to the user, it proved to be very beneficial to investigate the root of the problem in Solibri model checker.

7.3 Consistency model check

In the BIM workflow, Solibri is a very powerful piece of software to quality test and coalition control BIM models, but it is important to know how to apply it correct. If project partners are careless with modeling their individual subject, because they know errors will be detected in Solibri later on, this might cause an escalation in generated errors [Solibri]. This situation describes quite well the situation of the case study in this thesis, with numerous detected errors. These long lists of errors might lead to extended correction time, which is neither the intention of Solibri nor BIM [Solibri]. However, if Solibri is used early and consistently throughout a BIM project, for quality assurance prior to the model division into subject models (see figure 6.6), and later for coalition tests continuously throughout progress of the project, then it can serve as a key tool in the BIM workflow [Solibri]. In figure 6.6 the red dots illustrate appropriate times to conduct a Solibri model check, which conveniently could be prior to a coordination meeting or whenever something of significance is changed. This expression and illustration is intentionally very loose because the appropriate time to perform collision detection might vary greatly from project to project, what is important is that it is being done and used to coordinate models and eliminate inconsistencies.

In this project the possibilities of using Solibri was not used to its full potential because only one model were checked against a BIM validation ruleset. Since there was only a Revit architectural model and no subject models, consistency checks could not be performed. One of the very handy functions in the Solibri software is exactly its flexible use, in the way it allows the user to check against a large variety of rulesets or set up one's own for a specific project. The support of IFC and BCF formats makes the import/export and general communication to and from Solibri smooth. The author finds software like Solibri and Naviate essential for the collaboration of several models in any BIM project of a decent size. These programs are very diverse and provide crucial elements to the puzzle of performing a proper BIM workflow between software programs. Collision detection and smooth model transfer may not only save time and money during a project's design phases, but what might be even more important, is that the more problems and coalitions detected during these phases the fewer will be present in the construction phases. This is why the author believes that programs such as Solibri together with gbXML and BCF formats will be increasingly used in time to come throughout the AEC industry.

7.4 The author's personal opinion

Reflecting on the experiences during the preparation of this thesis with the limitations given in the case study due to its predetermined design, the author would have preferred to have been involved from an earlier design stage. It is a given that all projects will have certain boundaries, but by earlier and continued involvement from all participants in the design team, the conditions for performing a proper integrated design process would have been improved. The author finds the integrated design process much preferable compared to a process where the architect makes the first design and only then involves the engineers instead. The integrated design process does require a higher level of collaboration and quite possibly result in increased expenses during the design stages as the MacLeamy Curve in figure 3.3 suggest. However, this will easily be paid off by the savings in the operation of the finished building, which according to figure 2.1 accounts for 89% of the total building costs over its life time because it is designed better.

The author has yet to personally experience the full practical potential of fully incorporated BIM, but believes that the experiences gained during the case study, with the demonstrated benefits and the theory from section 3 (state of the art) illustrates BIM superiority to the document based workflow. Despite the many problems encountered in the model transfer process in the case study, the BIM approach came through as the better option under the proper circumstances, and proved beneficial in terms of eliminating remodeling and the ability to perform all three types of simulations in one single piece of software. The question of the proper circumstances by software, knowledge and collaboration is however essential.

8 Conclusion

The investigations in the thesis were made to test the hypothesis:

"Utilizing the full potential of BIM and advanced building design simulation tools will enhance the integrated design process related to a building's energy consumption and indoor environment between architects and engineers."

The hypothesis has been tested based on a literature study on relevant aspects of BIM and a case study where the IED and BIM were practiced under the given circumstances through a comparison of the conventional document based approach and the model based approach. The parameters tested in the investigations of optimizing the daycare institution were: indoor climate, energy consumption and daylight situation and related to the BIM workflow: benefits, which party has the benefits, procedure and constraints/drawbacks in relation to the exchange from the architectural model to the building simulation model which has resulted in the following conclusion:

8.1 The case

The case study has illustrated that use of gradually more complex calculation tools throughout the stages of the integrated design process, aided the building service engineer in the thesis perform calculations of appropriate detail level in each stage. At the conceptual design stage TCD was used to provide estimates of necessary ventilation rates and type of solar shading based on the building properties determined at that point. This information can be used as feedback to the architect for general design determination, but due to the circumstances of the case the results was used exclusively for estimations of input for more advanced simulation programs. Similarly a simple model from SketchUp was transferred to Daysim for early daylight assessment analysis and feedback to the architect. As more details were determined by the design team, increasingly complex software was used for proper analysis. However, any result will always reflect the circumstances of which it was conducted. In the case study, many of the design boundaries were determined prior to of involvement of engineers thus the changeable parameters were very limited. This affected the outcome of the building's passive design properties and palliatives in the form of PV panel proved to be necessary to bring the building's energy consumption within the BR15 requirements.

The case study showed through simple as well as more complex building simulation tools, that external solar shading was preferable, and that there is a demand for cooling to be added to the ventilation air in the common rooms during some periods of the summer months. These rooms were highly exposed due to their orientation toward southwest and a high occupant loads of more than one person for every 2 m^2 ($44m^2/25$ persons) at peak times. In the original Bsim simulation by Esbensen a scenario with a VAV system with an air change of up to $7h^{-1}$ at peak times during summer and no cooling was tested, but did not reduce the amount of overheating hours enough to fulfill the demands of BR15. Instead with cooling applied when the summer temperature exceeds 24°C and 22°C during day and night respectively, it was proved to be possible to reduce the mechanical VAV ventilation rate to just $3h^{-1}$ at peak periods. This means a reasonable reduction of the air handling unit and the ventilation ducts not to mention the energy consumption used for ventilation. This solution obviously causes energy demand for cooling applied to the inlet air which is reflected in the total energy consumption calculation. The IES<VE> simulation further confirmed that the kitchen and the office had no demand for cooling, because of low internal gains. With the determined ventilation strategy, the atmospheric indoor climate requirements were fulfilled during 97% of the occupied time in the Bsim simulation, and the entire occupied time according to the IES<VE> simulation.

In the dynamic simulation from IES<VE> the energy consumption of five representative rooms did not live up to regulations in BR15. When applying the results from this simulation, the original Be10 calculation was adjusted to a tailored Be10 calculation which came just short of fulfilling the BR15 energy demands. Results from the three calculations can be seen in table 8.1.

Table 8.1 - Simulated energy consumptions

	Original Be10	IES<VE>	Tailored Be10
[kWh/m2 pr. year]	42.5	62.7	49.6

The Original Be10 is simulation on the basis of an indoor temperature of 20°C, where as the latter two simulations are based on an indoor temperature of 22°C.If the tailored Be10 calculation is set to 20°C the result is 44.5 kWh/m^2 pr. year, only 1.2 kWh/m^2 pr. year more than the requirement.

The tailored Be10 can fulfill the requirements with an additional 7m^2 PV panel area on top of the 25m^2 included in the original Be10 calculation. The daylight simulations of the common room illustrated that the 2% minimum daylight factor requirement was not complied with in the back corners opposite the skylight and a narrow middle section of the room. Hardly any design changes could be made to any of the rooms and in the kitchen and office the 2% daylight factor boarder line is approx. 2.8m and 2m respectively from the façade. See figure 8.1 for details.

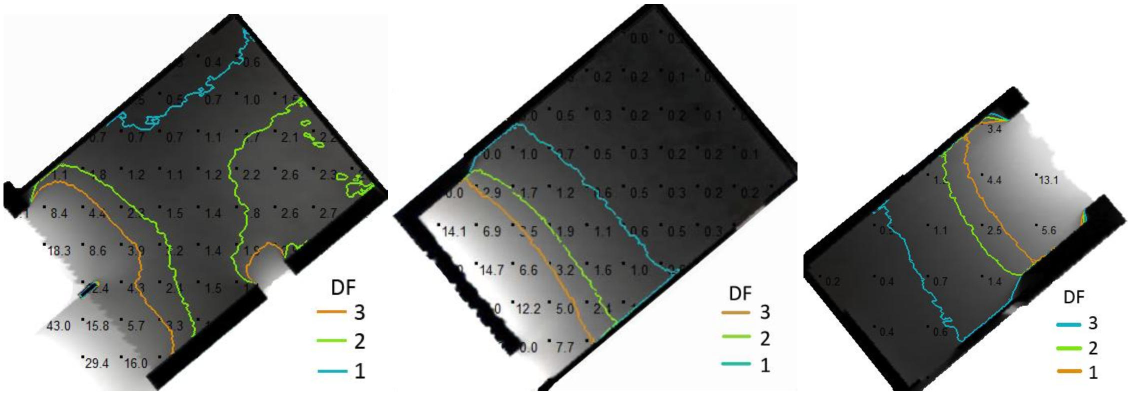


Figure 8.1 – Daylight factor distributions in the common room (left), kitchen (middle) and office (right). (Relative room sizes are not correctly illustrated).

8.2 The BIM workflow

Based on the investigation aspects of the BIM workflow the conclusion of the stated investigation areas are subdivided and explained in the following:

Benefits - Even though the model transfer from Revit to IES<VE> through the gbXML format is strictly speaking not a fully operational BIM model exchange because it does not support transfer of e.g. the correct building components; under the right circumstances, it can sill involve significant time savings by elimination remodeling. The same goes for the SketchUp to IES<VE> model transfer, if this is the choice of design tool. Where these transfers differ from one another is the fact that aside from Revit models being capable of transfer to IES<VE> these two programs support the IFC format, which opens for a entire new spectrum of opportunities including interoperability with Solibri and the BCF format for consistence- and coalition control and model correction. Additionally, the imported model in IES<VE> is fully capable of performing all three building simulation analysis dealt with in the preparation of this thesis. Because of these benefits, and the fact that building models may be exported from Revit to IES<VE> in up to five different complexity levels, depending on the detailing accuracy and complexity required, the author feels assured that this little sub-section of BIM can enhance the integrated design process by smoothening the interoperability between the architect and the building service engineer.

Who harvest the benefits? – The focus of the thesis involves primarily direct benefits for the building service engineer because model transfer can eliminate remodeling at the receiver end. In a broader perspective, a higher degree of collaboration between parties can lead to a better working integrated design process and a better result for the client. In that sense the benefits actually may go back to the architect if the process leads to a sharing of project profit.

Constraints/drawbacks – Exchange of models not designed with this intention in mind, but strictly for use of one party is very difficult to transfer, and may as in this case, involve extensive model adjustments and simplifications. Consequently, it may be much more beneficial for the receiver to completely abandon a model, which is not designed for interoperability between software programs and start all over on the model. Even with a relatively small building model like the case study of this thesis, it was proved to be very time consuming and substantial modifications were necessary for the model to transfer properly (procedures described in section in section 6.1.2.1). This is why to get the most out a BIM workflow, it has to be well planned, collaborative and preferably conducted according to the project IDM. The relatively low complexity level in the plug-in transfer caused some model simplifications, which had to be manually adjusted in the receiving software such as the change of window sizes/LT -values.

Generally it is concluded that the three main areas of investment (software, education and collaboration) related to a collaborative BIM approach, proposed in the research project [ØG-DDB, 2012], was confirmed and proven to be a prerequisite during the case study of this thesis. This is to be interpreted in the sense, that in this case study both the architects and the author had access to the proper software, but lack of the right BIM knowledge, model creation and collaboration led to a complicated and cumbersome exchange process. Considering the Revit to IES<VE> model exchange process, it has been experienced that the simplest geometry works best for transfer, since it is mainly a geometry exchange. Additionally, it is important to consider if the entire building model is necessary for analysis or only certain parts of this, because the analysis program has vast possibilities, but setup is very time consuming and might not be relevant.

9 Literature list

9.1 Articles and reports

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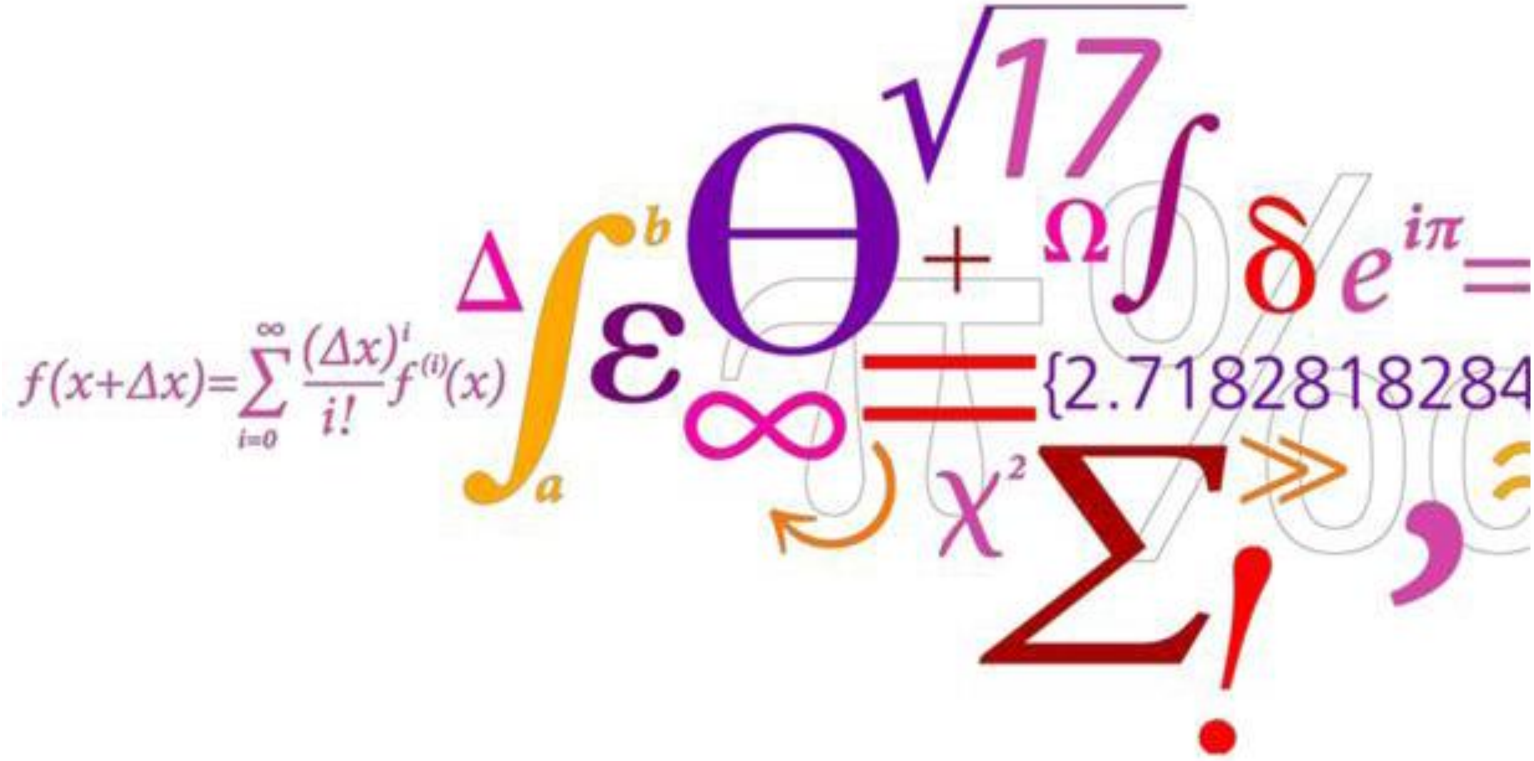
10 Appendixes

Appendix	Specification
A	[Rubow1]: Building Program
B	Description of Preliminary Design
C	Glazing properties
D	BIM “State of the Art”
E	Solibri generated material (Rulereport, ITO etc.)
F	Examples from Solibri
G	Original Be10 calculation & Tailored Be10 calculation
H	Daylight factor illustrations incl. RadianceIES simulations
I	TCD
J	Growth charts
K	Bsim simulations
L	Model exchange from Revit to IES<VE>
M	Inputs and results from IES<VE>

Technical University of Denmark

Integrated Energy Design and use of Building Information Modeling applied in a case study on a daycare institution



Appendix Report

Master Thesis
Daniel Løvborg s062467
DTU - Kgs. Lyngby - February 2013

DTU Civil Engineering
Department of Civil Engineering

RUBOW
arkitekter

Byggeprogram

Ny Daginstitution Tranehavevej 15

Udsendt: 5.6.2012
Sag nr.: 1051

1 FORUDSÆTNINGER

1.1Ejer/administrator

Københavns Kommune
Fritids & Kulturforvaltningen
Københavns Ejendomme
Nyropsgade 1,5
1602 København V
Kontaktperson: projektleder Lasse Bang.

1.2 Bygherre

Københavns Kommune v.
Københavns Ejendomme v. projektleder Lasse Bang, tel 26 73 43 24 (bygning)
Børne- og Ungdomsforvaltningen v. projektleder Mette Katrine Schrøder, tel 51 68 00 43 (pædagogik)

1.3 Opgaven

Opførelse af ny selvejende, integreret daginstitution på ca. 1050 m2 med plads til max 111 børn fordelt på til hhv tre børnehavegrupper og tre vuggestuegrupper.

1.4 Eksisterende forhold

Institution Børnehuset Bavnehøj er i dag en selvejende institution med 67 børn fordelt på 24 vuggestuebørn og 43 børnehavebørn. Institutionen flytter ved byggeriets afslutning til den nye institution. Daginstitutionen vil også fremover være selvejende.

Nabogrunden, som udgør den fremtidige grund for institutionen, anvendes i dag som boldbane for den nærliggende folkeskole. På grunden står et større skur, som tilhører skolen. Dette forudsættes nedrevet. Det er ikke afklaret, hvorvidt skolen fremover skal benytte Tranehavevej 17-19 som boldbane. I så fald må byggesagen pålægges at reetablere skuret på denne grund.

1.5 Grundforhold

Grunden udgør del af matr.nr. 18e og hele matr.nr. 1780, Valby. I alt ca. 3.000 m² grundareal. Grundens adresse er Tranehavevej 15, 2450 København S.

Området henligger som ubenyttet asfaltbelagt plads med hockey-bane. Der er opført et ca. 50 m² stort skur i den nordlige ende, som efter det oplyste benyttes af skolen på modsatte side af Tranehavevej. I det sydøstlige hjørne er opstillet en transformator.
I randen af området er der hele vejen rundt tæt bevoksning med buske og træer. Det har ikke været muligt at opmåle enkeltstammer pga. den tætte bevoksning. Bevaringsværdige træer markeres således at der evt. kan foretages supplerende opmåling når krat og buske er ryddet.

Området er mod alle side afgrænset af trådhegn.

Matr.nr. 18e er en større ejendom, som foruden opmålingsområdet også omfatter Tranehavevej og Nathalie Zahles Vej. Opmålingsområdets afgrænsning følger langs Tranehavevej en eksisterende vejudlægslinie. I den sydlige del af området løber vejudlægslinien – Nathalie Zahles Vejs forlængelse – dog inde på området.

Matr.nr. 1780 er et lille trekantet areal, registeret med 134 m², heraf 29 m² vej, der udgør en selvstændig matrikulær ejendom. Matr.nr. 1780 er udstykket fra matr.nr. 17c i 1929. Københavns Kommune erhvervede ejendommen i 1931.
Vejudlægslinien over matr.nr. 18e og 1780 stammer fra slutningen af 1920'erne. Det er uklart, om Nathalie Zahles Vejs forlængelse på et tidspunkt har været anlagt ind over området, svarende til vejudlægslinien, eller om der blot er tale om en arealreservation, som aldrig har været udnyttet til vej.

1.6 Matrikulære forhold

Dannelse af en ny selvstændig ejendom til daginstitution på området kan ske ved, at en del af matr.nr. 18e arealoverføres til matr.nr. 1780. Den matrikulære afgræsning af matr.nr. 1780 vil herefter svare til trådhegnets placering, som er den naturlige afgræsning af området. Man må gå ud fra, at Nathalie Zahles Vejs forlængelse stadig skal høre under vejmatriklen matr.nr. 18e.
Ved at udnytte, at Københavns Kommune i forvejen ejer matr.nr. 1780, og at gennemføre ejendomsdannelsen som en arealoverførsel spares ca. kr. 8.400 (momsfrit) i afgifter og gebyrer til Staten og Kort- og Matrikelstyrelsen.

I den matrikulære sag bør vejudlægget ved Nathalie Zahles Vejs forlængelse samtidig justeres, således at det ikke overlapper den nye ejendom til daginstitutionen.

Såvel de nye skel som omlægning/sletning af vejudlæg skal godkendes i Teknik- og Miljøforvaltningen efter sædvanlig procedure for matrikulære sager.

Matr.nr. 1780 har ikke adresse i dag. I forbindelse med den matrikulære sag skal der tildeles ny adresse.

Den matrikulære sag skal gennemføres af en praktiserende landinspektør.

1.7 Bygningsregulerende forhold

Fremtidigt byggeri er omfattet af Kommuneplan 2011, del 1122. Området ligger i byzone i rammeplan Vesterbro / Kongens Enghave, d.v.s. området er afsat til boliger (3-6 ETAGER). Grunden må bebygges med 130 % i max 22 m.

Der skal etableres friarealer i størrelsesordenen 100 % af etagearealet.

Parkeringsnorm udgør 1 p plads pr. 200 m2.

Tranehavevej er en privat fællesvej.

Grundens størrelser muliggør en institution i en etage. Placering af den ny bygning skal analyseres i forhold til sol/skygge og bedst mulig udnyttelse af grundens friarealer i følgende principper. Bygningen skal holde sig 2,5 m fra skel. Der kan bygges skure på 2,5 m´s højde op til skel.

Parkeringspladser forventes ikke anlagt i første omgang, men arealet reserveres til en evt. fremtidigt etablering. Indtil da kan arealet anvendes som friareal/ankomstareal. Dette skal dog endeligt godkendes af myndighederne.

Der tages så vidt muligt udgangspunkt i eksisterende træplantninger.

1.8 Forundersøgelser

Der er ingen viden om forureningsgrad på grunden. Plan for miljøundersøgelser, geotekniske boringer, vandspejlsboring og nedsivningsanalyse er under udarbejdelse. Det forventes, at jord i områder med afskrællet asfalt er forurenet i sædvanlig grad for byområde.

1.9 Servitutter

På matr.nr. 18e er tinglyst flg. servitutter:

19.08.1912 Fjernelsesdeklaration
Ikke til hinder for opførelse af ny institutionsbygning.
Dokumentet pålægger ejeren af matr.nr. 18e at fjerne bygning på egen bekostning, når det forlanges af enkefru Groot. Det er ikke klart, om deklarationen vedrører den aktuelle del af matr.nr. 18e.

21.08.1929 Dok. om byggelinier, vej mv. *Skal indgå i projekteringen for ejendommen. 3 ck@ckland.dk CK-Landinspektørerne www.ckland.dk CVR nr. 30178793*

Deklaration fastlægger byggelinie 12,5 m fra vejmidte langs Tranehavevej.
27.02.1932 Bebyggelsesplan
Skal indgå i projekteringen for ejendommen.
Dokumentet pålægger, at arealet imellem Tranehavevej og byggelinien, jf. dekl. tinglyst

15.07.1927, skal anlægges som forhave efter en af kommunen godkendt plan.
Dokumentets side 2 er fuldstændig ulæselig pga. dårlig scanning i Tinglysningssystemet, så det er ikke muligt at redegøre for det øvrige indhold af deklarationen. Jeg bestiller kopi af deklarationen i kommunens byggesagsarkiv. Under alle omstændigheder vil bebyggelsesregulerende bestemmelser i deklaration kunne aflyses med kommunen som påtaleberettiget til servitutten.

05.11.1935 Dok. om udlæg af areal til gader
Skal indgå i projekteringen for ejendommen.
Deklaration om udlæg af areal til Tranehavevej og byggelinie langs hermed (se også dekl. tinglyst 21.08.1929 og 27.02.1932).

10.11.1947 Dok. om højdebegrænsning
Ikke til hinder for opførelse af ny institutionsbygning.
Dokumentet pålægger 25 m højdebegrænsning ift. lufthavnsindflyvning.

30.10.1979 Dok. om transformerstation
Skal indgå i projekteringen for ejendommen.
Dokumentet giver Københavns Energi ret til at placere transformerstation i det sydøstlige hjørne af matr.nr. 18e. Iflg. deklarationens kortbilag løber ledningerne direkte ud til Tranehavevej, og er derfor formentlig ikke til hinder for ny bebyggelse på opmålingsområdet.

23.01.1995 Dok. om fjernvarme
Ikke til hinder for opførelse af ny institutionsbygning.
Dokumentet pålægger pligt til at aftale fjernvarme.

26.04.2006 Dok. om transformeranlæg
Ikke til hinder for opførelse af ny institutionsbygning.
Dokument om navnændring hos Københavns Energi.

2 PROJEKTET

2.1 Pædagogisk vision

Den nye institution skal bygge videre på sine eksisterende værdier omkring et udviklende miljø, hvor kvalitet og faglighed er i højsædet. Der skal være fokus på betydningen af omsorg, trygge rammer og trivsel for børnene, deres evne til at lære, lege og danne venskaber med hinanden. Det betyder bl.a. mindre rum, kroge nicher, en bevaring af spisefunktion på stuerne, og en udformning af grupperum og toiletter som én samlet enhed. Det er vigtigt at de gamle traditioner og værdier kommer med over i de nye rammer som et samlet hus med fælles mål og værdier.

Den kreative profil giver en meningsfuld ramme for brugerne, og for den direkte sanseoplevelse i et autentisk miljø, som stimulerer nysgerrigheden og kreativitet hos børnene.
få et værkstedsrum, hvor fantasien kan tage over og hvor der er mulighed for at lukke døren, så vi samtidigt kan bruge rummet til storbørnsgruppen. Det er netop i værkstedsrummet, at børnene har mulighed for at styrke og øve sig i finmotorik.

Børn udvikler sig optimalt i glade og trygge rammer. Der ønskes samtidigt et kombineret rytmik-/motorikrum, hvor der er muligheder for forskellige former for bevægelse. I dag har børn desværre en tendens til at blive optaget af mere stillesiddende aktiviteter, så derfor anses det for meget vigtigt, at børnene får mulighed for at bevæge sig, når de er i vuggestuen eller børnehaven.
I dag er dørene åbne, når der ikke er en aktivitet i gang i de enkelte grupper. Det betyder, at alle børn og voksne kan færdes i hele huset, og at hele huset kan bruges ud i de yderste kroge, så der er mange flere legemuligheder. Det er vigtigt, at denne mulighed også er at finde i det nye hus, samt at der er (lydtætte) døre imellem stuerne, så personalet kan hjælpe hinanden med at holde øje med børnene i dagligdagen, sikre at de voksne ikke er alene på stuerne, og forbedre mulighederne for at samarbejde og hjælpe hinanden. Åbne døre og fri færden medvirker også til at børn, forældre og personale lærer hinanden bedre at kende.

De udendørs legearealer udformes med tanke på gode opsynsforhold, samtidigt med at børnehavebørn og vuggestuebørn skal kunne lege adskilt fra hinanden på én vild og én stille legeplads. Udearealerne skal sikre motiverende miljøer for både drenge og piger.

Projektet udvikles med fokus på inspirerende, rumlige oplevelser i børnehøjde, gode arbejdsforhold og arkitektonisk/bæredygtig kvalitet.

2.2 Funktioner og indretning

Institutionen indrettes med udgangspunkt i Byggeprogram for Daginstitutioner 2011.

Der er i byggeudvalget derudover udmeldt følgende funktionsønsker, som så vidt muligt forsøges indarbejdet i projektet:

Ankomst

- Vindfang med plads til fodtøj, så institution kan være så ren og sandfri som muligt, snav skal afvikles hurtigt.
- Forældre skal tage sko af i hovedindgangen / grov-garderoben. Kræver at forholdene er til det.
- Fra hovedindgang fordeles til de 2 afdelinger

Fællesrum

- Mulighed for modtage- og lukkefunktion i tilknytning til køkken.
- Område til fælles morgenmad, fra 10 til 30 børn. Evt. klapborde på væg.
- Maleværksted
- Rytmikrum

Grupperum

- Et utraditionelt hus.
- Vinduer i forskellig højde
- Indendørs sovefunktion (evt. kombineret med rytmik)
- Grupperum udføres med stillerum. Udtrækskøjer undersøges.
- Meget vægplads.
- Grupperum (stuer) skal kunne deles op med foldedøre, skydedøre e.l. Adgang mellem grupperum i hver afdeling i form af 'lydtætte' døre som en fremtidssikring (voksendøre m. høje håndtag.)
- Veranda
- Udsyn fra stuerne til vejen – i børnehøjde
- Ingen udgang fra stuer til legeplads (grundet snavs)
- Børnegarderoberne (specielt børnehavegarderoberne) er separate med direkte udgang ud til legepladsen - ikke 66 børnegarderober klistret op af hinanden. – og ikke en lang gang gennem hele bygningen.
- Direkte vinduesudluftning på badeværelserne
- Dobbeltdør fra fællesrummet til legepladsen
- Liggehal udføres uopvarmet med 24 krybber, øvrige vuggestuebørn sover på madras indenfor, i stillerum, direkte tilknyttet vuggestueafd. og i ro fra legepladsens vilde område.
- være dobbeltdør fra fællesrummet til legepladsen
- Liggehal helt op af huset.
- Skur på grund til bleer etc.
- En sluk alt kontakt ved hovedindgang.

Personalefaciliteter

- Den samlede størrelse på det faste personale vurderes at være 20, hvilket udløser 2 personaletoiletter.
- Voksengarderobe samles i et område med aflåste faciliteter.
- Centrale p-faciliteter, ikke for lange gåafstande, dog gerne i fred for det eksterne flow (forældre)
- Der tages hurtigt kontakt til myndigheder m.h.p. afklaring af parkeringsbehov på grunden, idet det vurderes, at der er gode p forhold på Tranehavevej i dag. Personalet kører ikke i bil.
- Centralt kontor og samtalerum
- Personalestue vil max anvendes af 10 pers. på samme tid, kan evt. mindskes i forhold til byggeprogramkrav. Behov i thekøk: kun kaffe/the og køleskab/vask.
- Produktionskøkken skal have direkte adgang i forb. med vareindlevering
- Køkkendepotet i direkte tilknytning til køkkenet - indhak til morgenspisning.
- Toiletvinduer også på voksentoiletterne

Inventar

- Det eksisterende inventar består af 2 grupper (3 år gamle) og 2 meget gamle grupper, hvor inventaret er meget nedslidt.

Udendørs

- Aktiv zone/stille zone
- Hvordan kan vi sikre os, at det bliver vildt nok for de store børn?
- Småbørnsområde skal kunne aflukkes efter behov.
- Naturlegeplads d.v.s naturlige legeredskaber og jord, sand, lille græsareal til picnic, træer og buske, ingen større 'kunstige' områder.
- Legepladsen er 3 år gammel, mange legeredskaber kan genbruges, landskabsarkitekt indarbejder så vidt muligt de gode ting fra legepladsen.

- Kørebane som veje
- Cykler i lukket kredsløb.
- Drivhus
- Samlingsplateau
- Læområder
- Der er ønske om veludvoksede træer på den nye grund
- Der skal være plads til at gemme sig, evt. mulighed for at bevæge sig helle vejen rundt om bygningen.
- Støjværn mod byggeplads har høj prioritet.
- Tranehavevej 17 har fået udskiftet jord for ca. 10 år siden.
- Skolens skur på byggegrunden skal genetableres på Tranehavevej 17.
- Kan bygningen ligge så langt mod gammel grund som muligt – parkering på vejen optrappes jo tættere vi kommer på skolen og fritidshjemmet + st5øj fra frikvarterene.

2.3 Organisation

Følgende organiseringsprincip er udarbejdet i samråd med brugerne:

TRANEHAVEVEJ NY DAGINSTITUTION
ORGANISATIONSPRINCIP FORELØBIGT 15.5.2012
RUBOW ARKITEKTER A/S

2.4 Arealer

Vedlagte arealskema redegør for forventede rumstørrelser.

2.5 Energikrav og koncept

Bygningerne opføres i lavenergiklasse 2015.

Der er udarbejdet et overordnet energikoncept baseret på udvalgte, gennemgående prioriteringer, der tager udgangspunkt i børnenes univers og personalets dagligdag.

I konceptet indgår følgende fokuspunkter:

1. Robusthed:
- Bygningsvoluminet tilpasset stedet med passive designtiltag (vind, sol/skygge etc.)
- Åbent/lukket bygningskrop
- Mulighed for zoneopdelt ventilering
- Så lidt teknik som muligt
- Bygningen skal ikke kunne ’bruges forkert’

2. Lokal afledning af regnvand
- Etablering af synligt nedsivningssystem som del af legeplads med pædagogiske tiltag
- Etablering af grønne tage

3. Indeklima
- Optimerede dagslysforhold med udgangspunkt i dagslysberegning for grupperum
- Optimering af udhæng/solafskærmning
- Anvendelse af lyse, bæredygtige materialer
- Integrering af akustikregulerende overflader
- Etablering af sivelofter med god luftcirkulationskomfort

Miljøplan udarbejdes med udgangspunkt i disse fokuspunkter og deres angivne virkemidler.

2.6 Risikoanalyse økonomi og tid

Forhold vedr. stikledning til fjernvarme er uafklaret. I den forbindelse undersøges mulighed for opvarmning via varmepumpe og fritagelse for fjernvarme. Løsningen kan have store økonomiske fordele på sigt i sammenligning med en evt. dyr opkobling til fjernvarme.

2.7 Tid

Kontraktbaseret tidplan er forsat gældende.

2.8 Økonomi

Budget og statusrapport fremsendes særskilt til bygherre.

Byggeriet forventes udbudt sammen med den ny daginstitution på Bavnehøj alle 40 i hovedentreprise med Rubow Arkitekter A/S som totalrådgiver. Entreprenør kan herved etablere en fælles byggeplads.

2.9 Myndigheder

Der er indledt kontakt med Center for Byggeri v. Suna Sirek Uldbjerg. Det forventes at afholde et formøde med Center for Byggeri og Center for Bydesign omkring parkeringsforhold, arkitektoniske bindinger og overordnede regler vedr. beregning af flugtveje, liggehaller og overdækkede arealer i begyndelsen af næste projektfase.

Parkering planlægges afviklet på egen grund med udgangspunkt i Kommuneplanskrav om 1 plads pr 200 m2. fordelt som følgende:
Handicapparkering: 1 x 17,5 kvm= 17,5 kvm
Leverandørparkering: 1 x 25 kvm= 25 kvm
Alm. parkering: 3 x 25 m2

Det undersøges nærmere, om parkering kan afvikles på Tranehavevej.
Cykelparkering dimensioneres som angivet i arealskema.

Der kan etableres op til 150 m2 skur uden at de indregnes i etagearealet.

Liggehaller skal medregnes i etagearealet i beregning af bebyggelsesprocent og bebygget areal, men ved beregning af størrelsen af friareal i forhold til institutionens etageareal, kan liggehal friholdes i beregningen, hvis der i øvrigt kan etableres et passende opholdsareal til børnene (Per Söderhamn)

Til etagearealet medregnes ikke areal til liggehal og skure, såfremt dette areal ikke udgør mere end 25 procent af det samlede etageareal (jf. BR10).

Til friarealet medregnes ikke altaner og legeplads på tag.

2.10 Kvalitetssikring

Projektets størrelse og funktion giver ikke anledning til særligt behov for eksterne konsulenter.

Brandprojekt udføres med udgangspunkt i eksempelsamlingen og krav iht BR10 for anvendelseskategori 6 byggeri. Institutionen forventes udført som én brandsektion.

Akustikprojekt beregnes af leverandører.

Plan for sikkerhed og sundhed udarbejdes parallelt med projektering.

Der udføres tværfaglig kvalitetssikring i forbindelse med udarbejdelse af hovedprojekt/udbudsmateriale.

Bilag til byggeprogram:

Arealoversigt
Bæredygtighedskoncept
Målsætning legeplads
Foreløbige disponeringsskitser

INDHOLDSFORTEGNELSE

1.0PROJEKTORGANISATION

Ejer/administrator
Københavns Kommune
Fritids & Kulturforvaltningen
Københavns Ejendomme
Nyropsgade 1,5
1602 København V

Bygherre
Københavns Kommune v.
Københavns Ejendomme v. projektleder Lasse Bang, tlf. 26 73 43 24 (udførende)
Børne- og Ungdomsforvaltningen v. projektleder Mette Katrine Schrøder,
tlf. 51 68 00 43(bestiller)

Totalrådgiver
Rubow Arkitekter a/s
Skt. Annæ Passage F, 1
Bredgade 25
1262 København K
Kontaktperson: Susanne Hansen, tlf.: 33 69 11 94

Underrådgivere
SlothMøller, rådgivende ingeniører A/S
Møllegade 56
6400 Sønderborg
Kontaktperson: Per Schrankenmüller, tlf.: 40 42 91 57/73 42 31 57

Esbensen, Rådgivende ingeniører A/S
Gammel Køge Landevej 22
2500 Valby
Kontaktperson: Lars Printz, tlf.: 88 27 33 02

Opland Landskabsarkitekter ApS
Rådmandsgade 45A, 2. sal
2200 København N
Kontaktperson: Margrethe Holmberg, tlf.: 33 93 15 06

Myndigheder
Københavns Kommune
Center for Bydesign. Kontaktperson: Jan Kendzior
Center for Byggeri. Kontaktperson: Suna Sirek Uldbjerg
Center for Miljø

2.0 HOVEDDISPOSITION

2.1 Opgaven

Nedrivning af eksisterende skur.

Opførelse af ny selvejende, integreret daginstitution på 977 m² til hhv. tre børnehavegrupper og tre vuggestuegrupper. I forlængelse bygges en liggehal på 46 m².

Byggeriet vil skabe rammer for et udviklende miljø, hvor der er tryghed for trivsel og nærvær. Projektet har fokus på at skabe inspirerende, rumlige oplevelser i børnehøjde og samtidigt give gode arbejdsforhold for personale og medarbejdere.

Byggeriet vil være fremtidssikret arkitektonisk og have stor bæredygtig kvalitet.

2.2 Eksisterende forhold

Institution Børnehuset Bavnehøj er en selvejende institution med 67 børn fordelt på 24 vuggestuebørn og 43 børnehavebørn. Daginstitutionen vil også fremover være selvejende.

De omgivende nabobebyggelser er i gulmuret, tegl med 45 graders taghældning og fremstår i 3-4 etager. Denne bebyggelse danner en ryg øst og syd for grunden, hvorimod grundens øvrige kanter mere er præget af lave skure og beplantninger med bagvedliggende træbevoksning som tilhører Vestre Kirkegård. Der er plads til stilhed i en travl hverdag.

Beplantningen tilstræbes bevaret i det omfang det er muligt. Bevaringsværdigt beplantning reetableres ved skade eller fældning.

Se bilag - ejendomsrapport

Grunden har gennemgået en undersøgelse af overfladejorden iht. 50 cm reglen i jordforureningsloven §72b. Jordforurening er kortlagt til jordkvalitetskriterierne i niveau med kl. 3-4 jord. Overskridelserne skyldes overvejende indholdet af kulbrinter.

I forbindelse med ændret arealanvendelse til børneinstitution, skal de øverste 50 cm afgraves og erstattes med 50 cm dokumenteret ren jord. Al afgravet jord skal bortskaffes til jordrenser som forurenet jord. Pga. grundens kotering/terræn vil en stor del at forureningen kunne håndteres ved direkte påfyld.

Der søges om en §8 tilladelse inden opstart af byggeriet.

Se bilag - analyserapporter, geoteknisk rapport

2.3 Grunden

Grundens adresse er Tranehavevej 15, 2450 København S

Grunden udgør en del af matr.nr. 18e og hele matr.nr. 1760, Valby. Der skal udføres en matrikelsammenlægning af en del af matr.nr. 18e og hele matr.nr. 1760. Dette tinglyses og nye skellinier skal godkendes af Teknik- og miljøforvaltningen, Københavns Kommune.

Grunden udgør 3000 m².

Eksisterende skur på ca. 50 m² nedrives i forbindelse med byggestart.

2.4 Lokalplansforhold

Der foreligger ikke lokalplan for området og der er heller ikke krav om udarbejdelse af ny lokalplan. Gældende kommuneplan skal følges. Grunden ligger i byzone i rammeplan Vesterbro/Kongens Enghave, dvs. der må bebygges 130 % i en højde op til 22 meter.

Der etableres friarealer i størrelsesordenen 100 % af etagearealet.

2.5 Parkeringsforhold

Krav til bilparkering fra myndighedernes side iflg. kommuneplanen er mindst 1 parkeringsplads pr. 200 m², højst 1 pr. 100 m². Krav til cykelparkering er 1,5 pr 100 m² nybyggeri. Dette svarer til 5 pladser

Iflg. oplæg fra BUF skal der udlægges areal til 3 p-pladser, heraf en handicapplads samt en plads til vareaflevering. Der findes i dag betalingsfri parallelparkering i gaden. Udlæg kan udføres med max 5 m overkørsel. iflg. kommuneplanen skal der anlægges 4 p-pladser. Ifg. Aftale med Center for Byggeri, følges BUF's angivne parkeringsbehov.

Der etableres 2 stk. p-pladser samt 2 stk. handicappladser, hvoraf den ene kan bruges til vareaflevering.

Jf. byggeprogrammet skal der etableres cykelparkering til forældre svarende til 5 pladser pr. gruppe, samt overdækket cykelparkering til personalet - 0,5 plads pr. ansat, i alt 30 pladser. Behovet for cykelparkering vurderes at kunne imødekommes ved overholdelse af myndighedernes krav. Der etableres således 11 overdækkede pladser, samt plads til 6 ladcykler.

Se bilag - vedr. parkeringsbehov

2.6 Arkitektur

Arkitektonisk idé

Den nye selvejende børneinstitution på Tranehavevej er en institution i tæt kontakt med naturen med mange rum og nicher placeret i overgangen mellem ude og inde. Den organiseres i 3 hovedområde; vuggestuen i nord, fælleshuset i midten, og børnehaven mod syd.

Institutionen er i 1 etage med et stort centralt teknikrum på 1.sal. Parkering, renovation og cykelparkering afvikles langs bygningens østfacade i respekt for de eksisterende træer. Mod vest fremstår en zoneinddelt legeplads, der vokser omkring bygningens sydlige facade og sammenbindes til en mindre grønnegård mod gaden inden den store spidsløn. Den grønne kant mod kirkegården bevares så vidt muligt som karaktergivende element på legepladsen.

Bygningen skal nedskaleres vha. opdeling i tag og facader som via fremspring og tilbagetrækninger laver små steder og kroge omkring bygningen. Samtidigt tillader kompositionen af vinduer i de forskudte bygningsdele, at der kan komme lysindfald fra nord, syd, øst og vest.

Ved at udføre facaden med trælister kan alle institutionens faciliteter samles i én bygningstruktur som giver enkelthed og overskuelighed. Man kan få fornemmelsen af et hus som giver lyst til ophold.

Alle vinduespartier etableres ud fra nøje hensyntagen til udsigtsforhold og de enkelte rums funktionalitet, således at grundens potentiale og bygningens indre struktur udnyttes maksimalt.

Endelig er bygningen udformet med udgangspunkt i barnets verden. Vinkehuler i facaden, rumlige opholdsarealer, farvesætning og motiverende legehjørner med forskellige taktile overflader er med til at skabe variation og oplevelse i dagligdagen.

Ankomst

Grovgardeoben leder direkte til hhv. børnehave, vuggestue, produktionskøkken og personaleafdeling. Hovedindgangen placeres i forbindelse med fælleshuset, og leder videre til en gennemskærende grovgarderobe med stor panoramaovenlys, hvor alt beskidt fodtøj opbevares i gruppebaserede indretningsmøbler. Rummet giver god plads til, at alle husets brugere og gæster kan beskytte eller skifte deres udendørs fodtøj som garanti for, at resten af institutionen er skofri og ren.

Herfra kan man komme videre via grov/vandværksted til legepladsens centrale overdækkede udeværksted, som også opdeler udearealerne i 'lille' og 'stor' legeplads. Her placeres også de 2 udetoiletter. Der er indarbejdet 2 tørrerum - ét til børnehaven og ét til vuggestuen.

Fra grovgarderobe fordeles til de to børneafdelinger.

Fælleshuset

Fællesrummet udføres som en serie sammenhængende rum der fletter omkring produktionskøkkenet og et centralt fællesdepot. I fællesrummets ene afdeling etableres pædagogisk køkken via åbning i væg mod produktionskøkkenet. Her gøres plads til podieopbygning for børnene, og et par borde til morgenmadshygge, eller samling omkring det selvproducerede mad.

Fællesrummets anden afdeling fremstår fleksibelt og kan både anvendes til rytmik, værksted, samling og fri leg med direkte adgang til stor veranda. Dagslys tilføres via glasfacade og et stort ovenlys.

Der er skabt en ekstra adgang til legeplads fra det ene grupperumsområde aht. logistikken i huset.

Børnehaven og vuggestuen
De to børneafdelinger udføres ens med udgangspunkt i en enkel rumopdeling bestående af 3 sammenbyggede huse repræsenterende 3 grupperum med tilhørende birum. Mod vejen etableres garderobe nicher med vinkehuler i facaden. Garderobe zonen er stor og anvendelig, anvist med foldeborde til arbejdet med mindre børnegrupper. Det er vigtigt at udnytte dagslys og udsigtsforhold også fra denne side.

Grupperum placeres mod legepladsen, og det enkelte grupperum opbygges af 2 elementer; det større grupperum med udgang til lille veranda og stillerummet med vinduesniche. Stillerum afskilles fra grupperum med en let væg som på et senere tidspunkt kan fjernes.

Puslerummet med toiletter placeres centralt i 'huset' med oplukkeligt ovenlys og fast vinduesparti ind mod grupperummet med udsyn herigennem til legepladsen. Vægge i alle puslerum udføres med fliser som er nemme at rengøre og alle gulve udføres med gulvafløb i en lys vinylbelægning. Der etableres brusefunktion i et toilet i børnehaven. Vægges males i farve
Depoter placeres som selvstændige rum i forbindelse med grupperum.

Mellem de 3 grupperum etableres almindelig dør, der sikrer lydkrav mellem rummene, udført med højt håndtag. Der er fokus på at bevare store vægflader til møbler og udsmykning/udstilling.

En børneafdeling kan underdeles visuelt ved at udføre forskellige farver på gulvene for hvert 'hus'. Herved kan f.eks. garderobezonen indrettes pædagogisk, idet 'man' bor på en særlig gulvfarve, og ens ting ikke må overskride denne farve.

De små private verandaer fungerer dels som solafskærmning, dels som en lille privat udendørs zone i relation til hver gruppe. Dette betyder dog ikke, at der skal være udgang fra grupperum til legeplads i det daglige. Fra legepladsen vil selve verandamotivet fremstå som små legehuse, man kan søge ly i.

Liggehal etableres ud mod det nordlige skel i skygge af både bygning og beplantning og med direkte adgang til både garderobe og legeplads. Liggehallen udføres uopvarmet og indrettes med 24 krybber og fokus på at skabe et attraktivt arbejdsrum. De større vuggestuebørn sover på madras indenfor, i stillerum, direkte tilknyttet vuggestueafdelingen samt i ro fra legepladsens vilde område. Madrasskabe opstilles lige ved udgangen til liggehallen.

De specielle rum – farver og materialer
Den faste indretning prioriteres omkring fællesrummet, facadernes opholdsmulighed og grovværkstedet/garderoben.

I fællesrummet udføres 2 store vægflader af træpaneler med skabe samt mulighed for nedklappelige bordplader. Spisezonen indrettes med plads til 10-20 børn.

I grovgarderoben etableres skovægge til 3 børnehavegrupper. I garderober flettes ydervæggens indvendige side med børnegarderober med åbninger i facaden.

Resten af bygningen fremstår i rolige materialer, d.v.s. hvide vægge og hvide træbetonlofter. Gulve fremstår i hver sin farve i de enkelte huse og stillerum kan males til specifikke stemninger eller udføres med grafiske tapeter.

Inventar
Løst inventar indkøbes af institutionen.

Personalefaciliteter
Personalefaciliteter er orienteret mod den rolige gadeside. Adgang hertil kan ske direkte fra vindfanget for at skabe maksimal ro i børneafdelingerne. Kontoret ligger først der er flankeret af samtale/arbejdsrum og personalestuen, har et stort vinduesparti mod nord. Personalestuen udføres med tekøkken samt indeholdende et køleskab og en håndvask med plads til elkoger, kaffemaskine ell.lign.

Produktionskøkkenet placeres med udsyn over legepladsen, og får herved en pædagogisk funktion som centralt holdepunkt for institutionen. Vareindlevering sker via grovgarderobe. I tilfælde af sparerunde kan gang til legeplads i vuggestueafdelingen fjernes og grovgarderobe gøres smallere.

Personalegarderobe placeres sammen med personalebad nær hovedindgangen i relation til vaskeri.
Der etableres et personaletoilet i hver afdeling.

Personalet kan få taskeskabe i relation til de respektive børnegarderober. Legepladsjakker kan opbevares i grovgarderoben.

Udvendigt etableres overdækket cykelparkering ved hovedindgangen og renovationsskur i forbindelse med liggehal/barnevognsskur i tilknytning til Tranehavevej.

2.7 Materialer og farver

Bygningen udføres i materialer som er taktile og robuste. Det giver et hus som er rart at røre ved og samtidigt er holdbart. Vi forsøger at opbygge huset i naturmaterialer som ikke behøver efterbehandling, hvor det er muligt og hensigtsmæssigt – en efterbehandling skal altid vedligeholdes.

Anvendelse af lyse, bæredygtige materialer.

Der anvendes trækonstruktioner, beton, gulve på strøer med gulvvarme, Vinyl og gummi/linolium, gips- og træbetonlofter. Vinduesrammer fremstår udvendigt i rå aluminium og indvendigt i træ med klar lak. Ved specielle rum tilføres træpaneler i nordisk fyr eller birk. Facader udføres i varmebehandlet træ, der er udviklet til at fremstå ubehandlet. Alle materialer kan nedbrydes, og mange af dem kan genanvendes, heriblandt trækonstruktioner, letbetonelementer og rå aluminium. Hvis muligt bruges materialer som er Svanemærket eller med anden miljørigtigt anerkendelse – ex. beklædes hele huset med svanemærket træbeklædning.

Tag

En del af taget udføres som grønt tag for at fremme det omkringliggende grønne miljø. Resten af taget udføres som traditionelt paptag – grå.

Et grønt tag er et tag med planter som belægning – stenurt eller græs. Beplantningen lægges på et traditionelt tagpap tag og derfor koster denne løsning ekstra, da der er tale om et ekstra lag.

Grønne tage skal vedligeholdes – andre spirende planter skal fjernes så det ikke ødelægger den opsugende effekt som gør grønne tage attraktive, da de forsinker regnvand i at nå offentlige afløbssystemer. I tørre perioder skal taget vandes så de ikke udtørrer. Ved udtørring udskiftes alle planter. Hvis der ønskes en løsning som forsinker regnvand skal der vælges græs som har stor sugeevne.

Der kan opstår fugtproblemer ved grønne tage, hvis paptaget revner eller af anden grund bliver utæt. Hvis underliggende tagkonstruktion er udført i organiske materialer kan følgevirkningerne være skimmel eller svamp. Paptaget er til gengæld beskyttet af planterne og vil ikke som ved fritliggende paptage udtørre så ofte og derved revne og blive utæt.

Huset opbygges med lette tagelementer i træ og isolering. Dette er nødvendig for at opfylde krav om lavenergihus 2015, der kræver meget tykke og tætte konstruktioner.

Ydervægge

Huset udformes så det er rart at gå og opholde sig ved. Dette fremhæves med en listebeklædning af træ.

ThermoWood er fyrretræ som har fået en behandling der giver træet stor styrke og holdbarhed. Den bliver ved med at beholde formen og vrider sig næsten ikke med efterfølgende revnedannelser, hvilket er en stor fordel ved vedligehold af facaderne.
Vi vælger en lodret listeløsning som har en god tykkelse og som er monteret på bagvedliggende lister. Derved skabes en ventilation der er sundt for en trækonstruktion og som øder vedligeholdelsestiden.

Malet ThermoWood

Hvis ThermoWood males med heldækkende maling skal man først male igen efter 15-20 år. Samtidigt er det nemt at fjerne graffiti da denne kan males over.
Malet ThermoWood er den dyreste at købe men billigere at vedligeholde.

Behandlet ThermoWood
Hvis man ønsker at bibeholde den gyldne glød som ThermoWood har, anbefaler producenten at materialet behandles 3 gange ved fastgørelse og derefter vedligeholdt hver 4-5. år.
Hvor Listerne ikke er malet og kun er behandlet med pigmenteret træolie kan producenten ikke garantere at graffitien kan fjernes helt, da ThermoWood *er* træ som i tørre tider altid vil suge lidt.
Behandlet ThermoWood med pigmenteret træolie er næsten lige så dyr som malet og der er meget vedligehold.

Ubehandlet ThermoWood
Vælges en ubehandlet ThermoWood - altså som kun har fået en varmebehandling fra fabrik, ændres træets glød til at blive mere af "vejrbidt" karakter - hård, lysegrå. Graffiti kan ikke fjernes fra en ubehandlet uden en forebyggende behandling. Denne behandling kan ikke fjerne graffitien helt. Men området virker ikke til at være graffitikunstneres foretrukne sted. Ubehandlet ThermoWood er den billigste og har stort set ingen vedligehold.

Vinduer og døre
Der er valgt træ-aluvinduer og døre som har den egenskab at den stærke og vedligeholdelsesfrie aluminium er udvendigt og træ indvendigt. Træet er valgt lakeret med en farveløs lak så træet kan opleves. Begge materialer er naturprodukter hvoraf aluminiumet har fået en overfladebehandling som gør at den aldrig ruster.

Der isættes 3 lags energiruder aht. opfyldes af energidesignet. Det giver ruder hvor det indvendige glas ikke bliver kold om vinteren som gør ophold ved vinduer ekstra attraktive i den kolde periode.

Skillevægge
De fleste skillevægge vil aht. husets stabilitet være tunge vægge - letklinkebeton. Samtidigt har letklinkebetonvægge den egenskab at være lydisolerende, hvilket giver mulighed for placering af gruppe- og fællesrum ved siden af hinanden.

Øvrige vægge bliver opbygget som gipsvægge der fremstår jævne og lyse.

I alle puslerum opsættes hvide fliser i en højde af 1,4 meter fra gulv.

Akustiskregulering
Det er endnu ikke bestemt hvor den akustiske regulering skal placeres. Da loft er en del af akustikken skal reguleringen placeres lodret på væggene. Dette kan udføres som beklædning på væggene - som én stor opslagstavle.

Gulve
Gulvene opbygges som gulve på strøer der er med til skabe et godt indeklima og kan give sig så eventuelle fald ikke føles så hårde. Gummi- og linoliumsgulve er begge gulvbelægninger lavet af naturprodukter som begge er meget slidstærke og nemme at rengører.

Gummibelægning er opbygget som ét rent lag rågummi og skal med de rigtigt rengøringsløsninger, kun vaskes med rent vand. Det giver en ensartet ældning da man ikke har en behandlet overflade som skal holdes vedlige. Lydmæssigt har gummi en blødhed som kan absorbere mere og derfor bidrager positivt til efterklangstiden samtidigt med at det er trinlydsdæmpende.

Erfaringer viser at gummigulv på trods af deres egenskab som ét lag, dog er sårbar for ridser og slid. Dette kan skyldes forkert rengøring eller at materialet er for blødt til stærkt trafikale. Gummi er stadigt et "ungt" produkt i samligning med linoleum mht. brug som gulvbelægning og der sker forbedringer hele tiden.

Linoleumbelægning er opbygget af 3 lag, hvoraf det kun er toplaget som er et rent naturprodukt. Der er et mellemliggende lag som er vandafvisende - en fibermembran. Nederste lag er en lyddæmpende kork som er med til at dæmpe trinlyden. Linoliumet leveres med entynd, hård overfladebehandling som slides af der hvor der er mest trafik. Denne overflade kan vedligeholdes hver 5 år alt efter slid. Under denne overflade er naturmaterialet, linolie, harpiks og kalkstensmel. Det giver et såkaldt levende produkt som ved mindre ridser "genskaber" sig selv – det vil sige at overfladeridser ikke ses så meget.

Vinyl er valgt i alle vådrum med gulvafløb – de 2 andre belægninger er svære at gøre tætte ved afløb. Da vi har valgt gulve på strøer vælges en sikker løsning, hvor der er risiko for meget vand. Da Vinyl indeholder PVC som bindemiddel er den kun valgt i rum med meget lidt ophold.

Lofter
For at opnå gode lydforhold i gruppe- og fællesrum, er der valgt træbeton som er god til at optage lyd – dæmpe lyden i rummene. Der ligeledes ekstra krav i den gældende bygningsreglement(2010) som gør at træbeton ikke i sig selv er nok – se skillevægge.

Øvrige lofter er traditionelle gipslofter uden synlige samlinger – så dagslyset kan fordele sig jævnt og behageligt.

Lofter skal fremstå rustikke og lyse – hvide.

Fast inventar
Alt inventar som er fastmonteret udføres i lakeret Birk eller Nordisk Fyr

Resten af bygningen fremstår i rolige materialer, d.v.s. hvide vægge og hvide træbetonlofter. Gulve fremstår i hver sin farve i de enkelte huse og stillerum kan males til specifikke stemninger eller udføres med grafiske tapeter.

Se bilag – kort principiel bygningsdelsbeskrivelse

2.8 Konstruktioner

Konstruktive principper og hovedsystemer
De bærende konstruktioner udføres med træ-tagkassetter, bærende ydervægge og bærende skillevægge som udføres af elementer i letklinkebeton. Bygningen forventes at funderes direkte på bæredygtig jord. Fundamenter og terrændæk udføres i beton.

Konstruktive system for lodrette laster
Lodrette laster på taget føres via tagkassetter til de bærende yder- og skillevægge samt stålbjælker, hvorfra lasterne føres til fundamenter. Tagkassetter spænder på langs af bygningen.

Konstruktive system for vandrette laster
Der etableres vandrette skiver i taget og terrændækket. Vandret last (vindlast) overføres via etagehøje ydervægselementer til de vandrette skiver. Fra de vandrette skiver føres vandret last til de stabiliserende yder- og skillevægge og herfra føres de ned til fundamenterne og videre til bæredygtig jord. I den østlige facade opstilles indspændte stålsøjler til optagelse af vandrette laster på langs af bygningen.

Se bilag - SlothMøller, projektgrundlag

2.9 Landskab

Helhed
Legepladsen ligger hovedsagligt vest for bygning op mod Vestre Kirkegård, dog med en lille lomme syd og øst omkring huset ud mod Tranehavevej. Legepladsens udformning tager udgangspunkt i brugernes ønsker om en opdeling af små og store børn, samt ønsket om store og mindre rum til forskellige typer aktiviteter og frodige grønne omgivelser.

Legepladsen er opdelt i to zoner.

- Småbørnslegepladsen, nord for legeskuret
- Den store legeplads, syd for legeskuret

Langs bygningen etableres et slynget organisk sti forløb i hele bygningens længde. Stien er smallest i nord og syd og breddest på midten af grunden, hvor den bliver til en mindre plads der fungerer som fælles opholdsareal og buffer imellem den store og lille legeplads. Med sine slyngede bløde form skaber stien en god sammenhæng mellem natur, legeplads og bygning. I relation til grupperummene etableres et gennemgående trædæk, der sikrer niveaufri adgang til legepladsen fra alle grupperum via den centrale opholdsplads. I enderne er den ét trin høj, dvs. 15cm.

I legepladsens nordlige ende ligger et roligere lege- og opholdsområde til de små børn. Det består af en grøn plæne med masser af plads til leg, ophold og motorik øvelser på tæpper. Her er frugttræer, bær buske, en legehytte og højbede med urter samt et lille drivhus. En øst vestgående række af blåbær buske adskiller plænen fra et større sandområde. Sandområdet indeholder to mini legeborge og en nedgravet sandkasse med sandborde og solsejl.

Syd for sandområdet laves et område med redegynge for de mindste og en cykelbane for alle børn, dog primært de største. Den "lukkede" cykelbane udføres i asfalt med termoplast og bump til cykler, mooncars mv. og kantes mod pladsen af en 30 cm betonsidekant.

De store børns legeområde starter syd for udgangen fra grovgarderoben. Her anlægges et større sandområde med plads til tårnlegeborgen, samt den eksisterende redegynge. Her er også en nedgravet sandkasse med sandeborde og solsejl. Hække af ribs, hassel og spiræa omkranser området.

I legepladsens sydvestlige hjørne skabes et krat af hasselbuske, hvori der ligger en mindre balance- og motorik bane. Den består af forskellige stubbe og stammer, samt genanvendte legeplatforme på bakker. Her etableres også en lille bålplads, med siddemuligheder, så der kan laves snobrød og fortælles historier. I området anlægges også en mindre boldbane i gummi i nær tilknytning til stien.

På huset østside placeres det eksisterende shelter imellem grupper af buske og på et underlag af vildtvoksende græs. Under trækronen på den eksisterende spidsløn etableres et dæk, hvorpå forskellige aktiviteter kan finde sted.

Stier og faldunderlag anlægges, så der foretages mindst mulige anlæg indenfor træernes rodzoner.

Legeredskaber
Legeredskaber er primært genbrug fra den eksisterende legeplads. Der genanvendes en rede gynge, tre legeborge, et shelter, to legeplatform og tre sol sejl. Derudover tilføjes en ekstra redegynge, diverse stammer og stubbe samt en lille legehytte.

Alle faldunderlag overholder krav i DS/EN 1176/ DS/EN 1177.

Institutionen
- Legeplads areal: ca. 1525 m2

Pædagogisk formål
- Erfaringer til hele kroppen og alle sanser
- Naturoplevelser og årstidsvariation
- Grov- og fin-motorik, fysiske udfordringer og stille leg
- Aktiviteter, der stimulerer vestibulærsansen
- Åben leg og lukket leg, privat og social

Stisystem
- Der er 2 indgange til legepladsen fra Tranehavevej
- En slynget sti langs huset bliver til en mindre plads centralt på legepladsen. Kan benyttes som ekstra areal til cykler mv.

Materialer
- I legeområder er der faldgrus.
- I områder under træer er der bede i muld, træflis og arealer med enggræs
- Stier udføres med asfaltbelægning og fliser
- Kantafgrænsninger af asfalt er alukanter og betonkantsten.
- Faldgrus og sandkasser kantes med robinie sveller.

Hegn
- Legeplads indhegnes af galvaniserede panelhegn
- Hegnshøjde 1.5m
- Låger 1,2m bred med to lukkeanordninger
- Boldhegn 1.5m

Småbørnsleg (1-3år)
- Tryghedsfære - delvis afgrænset af en beplantning
- Nedgravet sandkasse, overdækket med solsejl
- Sandkorn 0-2mm
- To sandborde
- To mini legeborge
- Redegynge

- Plæne til stilleleg, motorik og leg på tæpper
- Lille legehytte på græsplæne
- Køkkenhave med drivhus, højbede, frugt- og blomstrende buske

Store børns leg (3-6år)
- Balance- og motorik bane af stubbe, stammer, små bakker og platforme
- Vildnis af hassel
- Bålplads
- Lille indhegnet boldbane med gummibelægning
- Cykelbane med termoplast til cykler, mooncars mm.
- Stor legeborg med to tårne
- Redegynge
- Nedgravet sandkasse, overdækket med solsejl
- Sandkorn 0-2mm
- To sandborde
- Shelter
- Trædæk til ophold, lege og show

Beplantning
Der skal tages særligt hensyn til det eksisterende rodnet af de eksisterende spidsløn som markerer institutionen mod Tranehavevej.

Legepladsen indrammes mod vest af en række store kirsebærtræer på Vestrekirkegård, samt en stor solitær poppel.

Legepladsens sydvestlige hjørne tilplantes som hassel krat, der kan fungere som hule, fange- og gemmelege. Derudover plantes der let spredte mindre frugttræer, som kan give årstidsvariation, rumdannelse og skygge. Frugttræerne suppleres af fem rækker af forskellige bærbuske og blomstrende buske, der giver variation og frodighed.

I højbede plantes div. krydderurter.

Inventar
- Mobile bord/bænke sæt

Belysning
- Der er belysning ved indgange til bygningen, samt vægarmaturer ved indgange på bygning

Afvanding
- Ved opholdplads og ankomstareal ledes overfladevand til riste i terræn.
- Vand på stier ledes til bede og grusflader og derfra forsinkelsesbassin.
- Vand fra tage og skure ledes vand til forsinkelsesbassin

Ankomstareal
- Cykelstativer med 50 pladser (heraf 12 overdækket langs bygning)
- Renovation: 6 x 240L renovationsbeholdere, 2 x 600L renovationsbeholder overdækket i skur mod nord.
- To almindelige p-pladser, én handicapplads og en plads til vareindlevering.

3.0 MILJØ- OG ENERGIDESIGN

3.1 Bæredygtigt koncept og miljøstrategi

Bygningerne opføres i lavenergiklasse 2015.

Der er udarbejdet et overordnet energikoncept baseret på udvalgte, gennemgående prioriteringer, der tager udgangspunkt i børnenes univers og personalets dagligdag. Bygningen skal i sit koncept være robust i valg af materialer og energidesign.

I konceptet indgår følgende fokuspunkter:

Bygningsvoluminet er tilpasset stedet med passive designtiltag.
Der er foretaget dagslysanalyser af grupperum og personalekontor i forhold til optimering af vinduesarealer og hensyntagen til skygge fra eksisterende træer.

Sol- og skyggeforhold er analyseret, og udearealer/udgange fra bygningen er placeret i forhold hertil.

Bygningen skaber via sin placering på grunden altid mulighed for at lege på en sol/læside.

Terrænspring optages som robuste, rumlige inddelinger af friarealerne.

Åbent/lukket bygningskrop
Bygningen er udformet meget kompakt men med højt til loftet med mulighed for, at gribe dagslys fra alle retninger via vinduer i facaden og ovenlys i tag, hvilket giver et rigt og nuanceret indeklima.

Bygningens overflader er minimeret, og klimaskærmen fremstår højisoleret og meget tæt.

Mulighed for zoneopdelt ventilering.
Ventilation udføres zoneinddelt i forhold til husets aktivitetsniveau. Dette giver mening i forhold til dagsrytmen for varierende børneintensitet. Det åbne fællesrum i midten udnyttes som ´skorsten´for supplerende naturlig ventilation i sommerperioden. Om vinteren giver ovenlyset til gengæld passiv solvarme til legezonen.

Så lidt teknik som muligt.
Jo mere passivt et hus er tegnet, jo mindre teknik er påkrævet for at tilvejebringe et optimalt indeklima. Der er fokus på styring og regulering af varme, ventilation og solafskærmning. Varmefordelingen sker via rør i gulve, således at huset fremstår uden radiatorer. Mekanisk ventilation foregår via sivelofter uden synlige, vedligeholdelseskrævende luftfordelingsaggregater.

Bygningen skal ikke kunne 'bruges forkert'
Der er i projektteamet ligeledes fokus på at aflevere et hus, som brugerne kan forstå, med en vejledende manual, der sikrer en konstruktiv dialog mellem brugerne og Københavns Kommunes driftsafdelingen.

Derudover er et robust og entydigt materialevalg afgørende for en fremtidig korrekt drift og lave vedligeholdelseskrav.

3.2 INDEKLIMA

Indeklimaet er projekteret og dokumenteret gennem kalkulationer, således at der bliver leveret et tilfredsstillende indeklima både termisk og atmosfærisk.

I sommerhalvåret er strategien at mindske mængden af uønsket tilført solvarme igennem mekanisk styret solafskærmning på vinduer der er orienteret mod syd, øst og vest. Det tilstræbes at solafskærmningen udføres via markiser. Det er dog ikke altid nok med markiser da solen på bestemte tider af året står meget lavt. Udhæng ved vinduer mod vest medvirker til begrænset solindfald og fungerer ligeledes som en del af solafskærmningen. Ventilationen supplerer solafskærmningen med et øget luftskifte i situationer hvor mængden af tilført varme i rummene overskrider et foruddefineret temperatur setpunkt. Der etableres motor på ovenlys, således at der kan åbnes manuelt ved tryk på en knap. I rum med ovenlys vil der ved åbning af vinduer i facaden og samtidig åbning af ovenlys, kunne opnås et ekstra luftskifte på op til 2 gange i timen afhængig af vind og temperaturforhold.

I vinterhalvåret bidrager solvarmen til gratis opvarmningen af rummene. Gulvvarmen etableres som "let" gulvvarme på varmefordelingsplader, hvilket har den fordel, at gulvvarmen hurtigere end traditionel gulvvarme, kan tilpasse sig rummenes vekslende opvarmningsbehov, og minimere risikoen for overtemperaturer.

Det atmosfæriske indeklima reguleres via CO2 følere, således at luftskiftet øges i takt med antallet af personer i opholdsrummene. Grænsen for CO2 koncentrationen i rummene fastsættes til 1000ppm svarende til arbejdstilsynets og bygningsreglementets krav.

Optimering af udhæng/solafskærmning i forhold til udsigtsforhold og solorientering.
De mange forskydninger og udbygninger med hhv verandaer og udhæng er med til at danne skygge på både facader og overgangsarealer mellem ude og inde.

Etablering af sivelofter med god luftcirkulationskomfort.
Disse lofter er samtidigt akustisk regulerende, og man undgår synlige luftfordelingsaggregater i loftspladerne.

Visuelle forbindelser på tværs.
Skaber både synergi og rumlige oplevelser. Det sammenbindende grovværksted fordeler dagslys ned gennem bygningens midte, og de mange ovenlys skaber behagelige forhold i husets dybe rum, mens vejret udenfor gøres let aflæseligt inde i husets kerne.

3.3 Energiramme

Målet for energirammen er overholdelse af lavenergiklasse 2015, hvilket betyder at energibehovet til rumopvarmning, opvarmning af brugsvand, og el til bygningsdrift ikke må overstige 43,4 kWh/m2 pr. år, idet der gives et mindre tillæg for en brugstid på 50t/uge.

Bygningens energibehov overholder forventningerne, dog med brug af solceller på tag. God solafskærmning i kombination med en velisoleret og tæt bygning betyder et lavt energiforbrug for bygningen. Der etableres 25 m2 solceller på taget over fælleshuset.

En vigtig energimæssig forudsætning er at bygningen skal kunne leve op til et tæthedskrav på 0,5 l/s pr. m2 ved trykprøvning ved 50Pa.

Se bilag – energiramme og ventilation

3.4 Dagslys

Se bilag – notat vedr. dagslysberegning

3.5 Lydkrav og akustik

Integrering af akustikregulerende overflader.
Der etableres ’store’ rum og ’højt til loftet’ for at give plads og volumen til aktivitet, og mere areal til akustikregulerende materialer. De øgede rumhøjder kontrasteres af nicher og stillerum, der til gengæld udformes mere intimt.

Der er udført akustiske beregninger som påviser en ekstra lydabsorberende foranstaltning i bestemte rum. Der etableres ca. 20 m² ekstra lydabsorberende foranstaltning i hvert grupperum. Der er afsat et beløb til dette i kalkuleringen.

Byggeriet udføres iht. BR10, 6.4.3, stk. 1.

3.6 Drift og vedligehold

Udvendigt vil der stort set ikke være nogen vedligeholdelse. Det grønne tag skal luges for andre beplantning inden denne bliver for stor, da andre rodarter vil skade det grønne tag og det underliggende underlag. Husk at vande taget ved længere tørre perioder. Udtørre taget skal det reetableres.

Indvendigt er rengøringen en del af vedligeholdelsen. Alle overflader kan støvsuges og vaskes. Alle vinduer kan rengøres fra stige.

Der placeres bevægelsesfølere som får lysarmaturer til at tænde og slukke efterhånden som man bevæger sig rundt i huset. Der er følere på vandarmaturer i puslerum og toiletter som bidrager til god hygiejne.

Solafskærmningen, brandtekniske anlæg og tyverialarm skal have serviceeftersyn. Der skal udskiftes filtre i ventilationsanlægget. Gulvafløb og vandlåse renses jævnligt.

Se bilag vedr. drift og vedligehold

4.0 INSTALLATIONER

4.1 VVS-installationer

4.1.1 Spildevand

Afløbssystemet anlægges som separate spildevandsledninger og regnvandsledninger, men samles i det offentlige fællessystem. Der er to tilslutningspunkter inde på matriklen, som kan benyttes såfremt der er kapacitet nok til at modtage vandet. Hvis ikke, kan der etableres et nyt stik, hvorefter ubenyttet gamle stik skal afproppes.

Der etableres omfangsdræn og terrændræn, som tilsluttes det øvrige regnvandssystem via drænpumpe. Tagvand opsamles og tilsluttes regnvandssystemet.

Regnvandet opsamles, inden udledning til det offentlige system, i et forsinkelsesbassin. Regnvand nedsives ikke på lokaliteten grundet de uegnede jordbundsforhold samt forureningsforekomster.

Der er spildevand fra toiletter, håndvaske, pædagogisk- og produktionskøkken. Der er desuden placeret to udvendige vandhaner, som også skal håndteres.

Der etableres fedtudskiller og prøveudtagningsbrønd fra produktionskøkkenet.

4.1.2 Tagrender og nedløb

Der udføres tagrender og nedløb i zink. Tagrender og nedløb forsøges skjult bag facadebeklædningen.

4.1.3 Afløb og sanitet

Afløb udføres med udluftning over tag.
Sanitet er hvid, i kvalitet som Ifö.
I puslerum monteres 2 stk. kummer i porcelæn.
Toiletter leveres i ekstra rengøringsvenlig porcelænskvalitet og er gulvmonterede.
I storkøkken monteres 1 stk. håndvask.
I HC toilet monteres håndstøtter.

4.1.4 Vand

Vandinstallationen udføres efter fordelerprincippet med centralt placerede indbygnings- fordelerskabe og rør derfra skjult til hver enkelt tapsted. Det varme brugsvand produceres i en varmtvandsbeholder i teknikrummet.

Der tilstræbes størst mulig brug af berøringsfri vandhaner. Vandhaner skoldningssikres i de rum hvor børn har adgang.

I puslerum monteres 6 stk. vandhaner ved kummer og 1-2 stk. vandhaner ved håndvask i hæve/sænkeborde.

I et personale toilet og et puslerum, monteres termostatbruser.

Tekøkken i personalerum og pædagogisk køkken forsynes med vand til opvaskemaskine og køkkenvask.

Storkøkken forsynes med håndvask, køkkenvaske, opvaskemaskiner og ovn med vand.
Der placeres 1 stk. udvendigt vandhane i facade ved storkøkken samt én ved udv. værkstedsområde.

4.1.5 Varme

Varmeforsyningen er fjernvarme og der etableres gulvvarme i alle områder. Gulvvarmen udføres med varmefordelingsplader og rør direkte under trægulvet. Dette gør at gulvet også reagerer forholdsvis hurtigt på gratis varme. Dermed reagerer de hurtigere på gratisvarme fra solindfald og personer, som kan påvirke den godt isolerede bygning en større del. Derved opnås en højere komfort og lavere energiforbrug. Gulvvarmen styres via et CTS-anlæg med føler i alle rum med gulvvarme.

Der foreslås radiatoropvarmning i depoter og vaskeri, og da det er et lavenergibyggeri behøver radiatorerne ikke at være så store. Overfladetemperaturen holdes under 50 °C for at undgå forbrændinger.
I tørrerum etableres både gulvvarme og radiatorer. Radiatorer placeres under bænke for at rummet kan opvarmes hurtigt og derved tørrer tøjet.

Varmeinstallationen udføres efter fordeler princippet med decentralt placerede indbygnings fordelerskabe i depoter og rør derfra skjult til hver enkelt gulvvarmekreds.

Liggerum er ikke opvarmet.

4.1.6 Ventilation

Hele bygningen ventileres iht kravene i bygningsreglementet og det følte indeklima. Luftskiftet dimensioneres ud fra antallet af børn og voksne samt det termiske indeklima. Den største luftmængde bliver det dimensionerende. Anlægget udføres med variable luftmængder i større rum med meget varierende personlast. Dette gør at co2-niveauet holdes lavt for at skabe bedst mulig komfort og samtidigt er energiforbruget lavest mulig. Ventilation styres via et CTS-anlæg med temperatur og CO^2 føler i rummene. Ventilationsaggregatet udføres med genvinding og placeres i Teknikrummet over depot. Kanalføring foregår skjult i vandret installationsskakte over birum i de 2 fløje. Kanaler er kun synlige under loft, i grov garderobe og mellem vaskeri og toilet over garderobe ved modul D.

Indblæsning i grupperum, garderober, kontorer sker via ventilationslofter uden synlige armaturer. Udsugning via armaturer i væg eller loft. Øvrige rum ventileres via loftarmaturer.

Der udføres separat ventilationsaggregat med krydsveksler til ventilation af storkøkken, hvor der udsuges fra emhætte over kogeplader og indblæses via synlig stofpose under loft.

4.1.7 Produktionskøkken

Produktionskøkkener udføres iht. budgetteret beløb i rammebudgettet samt kommunens bestykningsliste for køkken til 6 grupper. Endelig indretning udføres af producent.

4.2 El-installationer

4.2.1 Belysning og dagslysstyring

Belysningen udføres med lavenergi armaturer, tilpasset de forskellige benyttelsesområder.
Energibesparende foranstaltninger:

- Grundbelysningen udføres iht. kravene i DS700.
- I områder med dagslysindfald udføres dagslysstyring af belysning, med manuel tænd, automatisk sluk og mulighed for manuel dæmpning.
- I gangarealer, depoter o.lign. udføres belysningen med automatisk tænd/sluk vha. bevægelsesmeldere.
- Belysningsstyringerne udføres som Servodan eller tilsvarende standardsystemer, som er opbygget "inteligente", så f.eks. tænd/sluk funktioner og luxniveauer kan ændres uden omlægning af installationen. I større rum vil der blive fremført 2 stk. tændinger i disponible lampeudtag, så forskellige belysninger kan tændes separat.
- I alle rum installeres bevægelsesmeldere for automatisk sluk.
- Udvendig belysning styres af skumringsrelæ og ur, med manuel overstyring i eller ved eltavlen.

4.2.2 Lys- og kraftinstallationer

Der etableres i alle rum installationer for belysning, stikkontakter, samt faste brugsgenstande, som pusleborde, hårde hvidevarer mm. Omfanget af stikkontakter og tændinger udføres jf. følgende:

- Der etableres disponible lampeudtag i omfang iht. Byggeprogram for Daginstitutioner.
- Der etableres mindst 1 stikkontakt i alle rum pr. påbegyndt 5 m^2, Bortset fra toiletter, puslerum og sekundære rum, som depoter og loftsrum.
- Der etableres stikstationer i omfang iht. Byggeprogram for Daginstitutioner.

4.2.3 Elforsyning

Der etableres ny elforsyning til institutionen. I eltavlen placeres elmåler, med afregning til forsyningsselskabet. Stikledningen dimensioneres for 25% reservekapacitet.
Eltavlen opbygges med HPFI-relæer og automatsikringer. I rum med både disponible lampeudtag og grundbelysning, vil disse blive fordelt på 2 grupper, således at en totalmørklægning undgås pga. interne fejl i institutionen.

4.2.4 EDB/Krydsfelt

Der udføres kabling fra nettermineringspunkt til rackskab, herfra fremføres kablingen til arbejdspladser for EDB og telefon, AIA-anlæg, ABA-anlæg, samt til AIA/ ABA-anlæggets centralskab. Der etableres i teknikrum et rackskab i passende størrelse til patchpanerler, powerpaneler, switch og telefonanlæg.
Fra racket fremføres kabler til telefon- og edb-stik, UTP kategori 6
Der etableres føringsveje fra terræn til rackskab for etablering af nettermineringspunkt.
Aktivt udstyr leveres og monteres af bygherre.

4.2.5 Telefon/lydovervågningsanlæg

Der etableres telefon, dørtelefon og lydovervågningsanlæg iht. Byggeprogram for Daginstitutioner.

4.2.6 ABA-anlæg

Der etableres ABA-anlæg iht. DBI retningslinie nr. 232.

4.2.7 ABDL-anlæg

Der etableres ABDL-anlæg iht. DBI retningslinie nr. 231. ABDL-anlægget styres af ABA-anlægget.

4.2.8 AIA-anlæg(tyverialarm)

Der etableres AIA-anlæg iht. Byggeprogram for Daginstitutioner.

4.2.9 Antenne

Der etableres installation for 1 antennestik i fællesrum samt 1 antennestik personalerum.

4.2.10 Solceller

Der etableres komplet solcelleanlæg på ca. 25 m2 med monokrystallinske solcellemoduler placeret på sydvendt tagflade i plan med taget. Solcellemodulerne forbindes indbyrdes og tilsluttes vekselretter placeret et hensigtsmæssigt sted. I eltavlen etableres separat gruppe for solcelleanlæg, og i eltavlen opsættes målere af en type, der muliggør brug af nettomålingsordningen. Kabler dimensioneres så det samlede spændingsfald fra moduler til eltavle er maksimalt 1%.

5.0 MYNDIGHEDER

Der er afholdt møde med Center for Byggeri, Københavns Kommune generelt for byggeriet. Da udbygning med liggehal, renovation og depot, er placeret i skel og har større højde end tilladt for bebyggelse i skel, skal der søges dispensation. Hvis dispensation ikke gives skal udbygningen udføres med traditionelt fladt tag. Arkitektonisk vil en fortsættelse af det øvrige tag være at foretrække.

Brand

Byggeriet er i anvendelseskategori 6 og udføres i overensstemmelse med Eksempelsamling 1.

Ved mødet blev brandforholdene gennemgået. Bygningen holder sig under 1000 m² og skal derfor ikke sprinkles men inddeles i én stor brandsektion underinddelt i brandceller. Der udføres nødvendige flugt- og redningsåbninger samt brandtekniske foranstaltninger, ABDL- og ABA-anlæg.

Se bilag vedr. mødenotat – Center for Byggeri, d. 15.08.2012

6.0 AREALER

Se bilag – arealoversigt

7.0 ØKONOMI OG UDBUDSFORM

Byggeriet forventes udbudt sammen med den ny daginstitution på Bavnehøj Allé 40 som indbudt underholdsbud i hovedentreprise med Rubow Arkitekter A/S som totalrådgiver.

Entreprenør forventes at kunne etablere en fælles byggeplads, som planlægges i forbindelse med næste fase. Under byggefasen kan overvejs et adskille krattet fra selve byggepladsen som friareal for institutionen.

Budget
Der skal søges bevillig til ikke indeholdt udgift:

- Fjernelse og reetablering vedr. forurenet jord

I øvrigt
Løst inventar indkøbes af institutionen.

Se bilag – kalkulation

8.0 TIDSPLAN

Tidsplan for myndighedsprojekt og udførelsesfaser fremgår af tidsplan, dateret 06.08.2012. Det kan vise sig nødvendigt at justere tidsplanen i de følgende projektfaser men tidsplanen kan stadig følges efter denne fase.

Se bilag – tidsplan og handleplan

9.0 TEGNINGER

- Tegningsliste – arkitekt
- Arkitekttegninger
- Mappe (udleveret til brugerne)
- Tegningsliste – landskabsarkitekt
- Landskabsarkitekttegninger
- Tegningsliste – ingeniør
- Konstruktionstegninger
- VVS tegninger
- EL tegninger

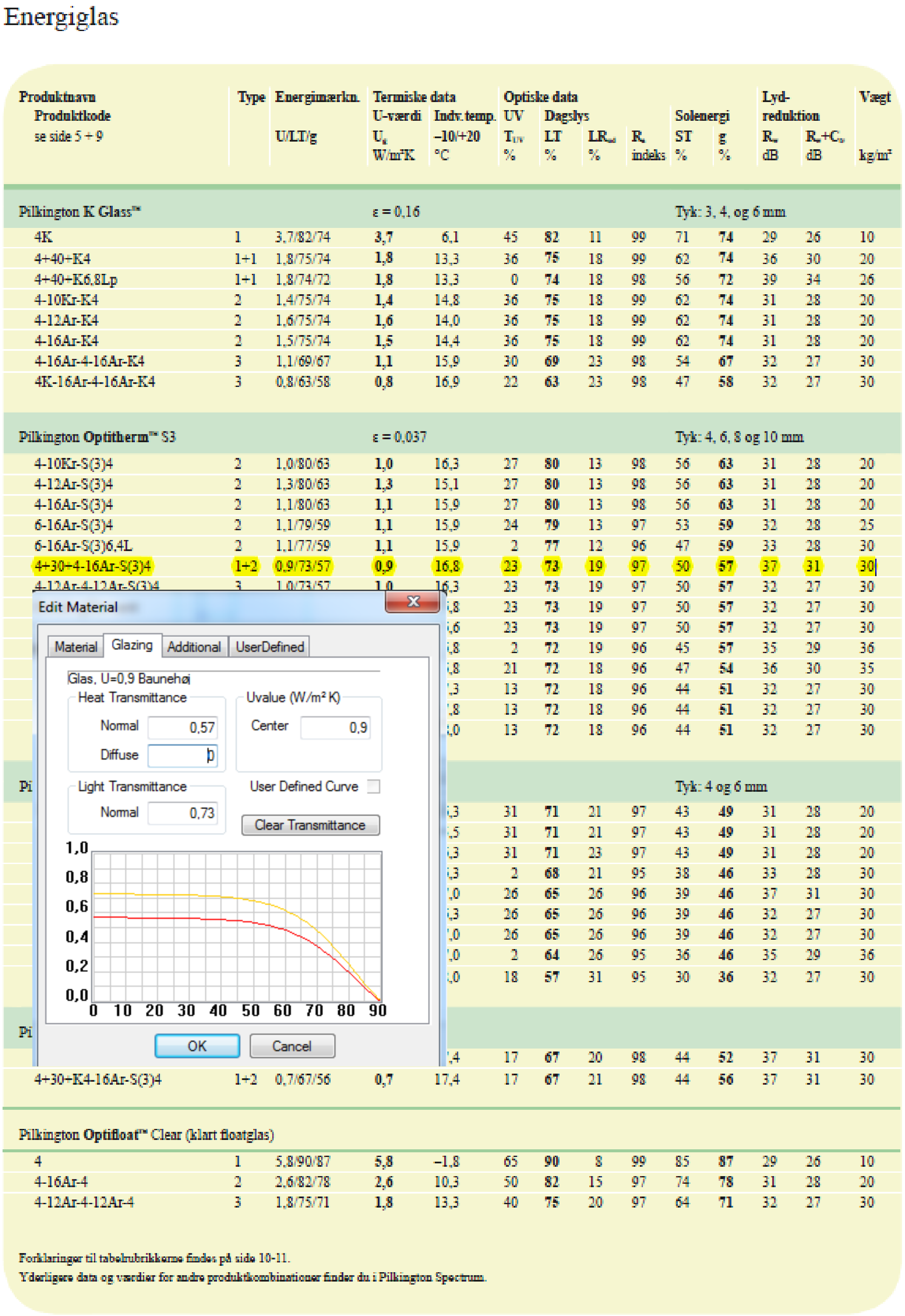
10.0 BILAG

- Kalkulation
- 285 overslag – landskab
- Drift og vedligehold
- Arealoversigt
- Notat – beskrivelse af ingeniørarbejder – projektgrundlag
- Notat – energiramme og ventilation
- Notat – dagslysberegning
- Tids- og handleplan
- Ejendomsrapport/tinglysninger – Landinspektør

- Situationsplan – Landinspektør
- Mødenotat – Center for Byggeri, d. 15.08.2012
- Kort principiel bygningsdelsbeskrivelse
- Miljørapport
- Analyserapport
- Generel bestykningsliste
- Bestykningsliste for produktionskøkken – 6 institutionsgrupper
- Geoteknisk rapport
- Bilag 02 Oversigt, parkeringsbehov

Appendix C – Glazing specifications from Pilkington

Façade windows (Pilkington energy glass)



Energiglas

Produktnavn Produktkode se side 5 + 9	Type	Energimærkn.	Termiske data		Optiske data						Lyd-reduktion		Vægt
			U-værdi	Indv. temp.	UV	Dagslys			Solenergi				
		U/LT/g	U_g W/m²K	−10/+20 °C	T_{UV} %	LT %	LR_{ud} %	R_a indeks	ST %	g %	R_w dB	R_w+C_{tr} dB	kg/m²
Pilkington K Glass™			ε = 0,16						Tyk: 3, 4, og 6 mm				
4K	1	3,7/82/74	**3,7**	6,1	45	**82**	11	99	71	**74**	29	26	10
4+40+K4	1+1	1,8/75/74	**1,8**	13,3	36	**75**	18	99	62	**74**	36	30	20
4+40+K6,8Lp	1+1	1,8/74/72	**1,8**	13,3	0	**74**	18	98	56	**72**	39	34	26
4-10Kr-K4	2	1,4/75/74	**1,4**	14,8	36	**75**	18	99	62	**74**	31	28	20
4-12Ar-K4	2	1,6/75/74	**1,6**	14,0	36	**75**	18	99	62	**74**	31	28	20
4-16Ar-K4	2	1,5/75/74	**1,5**	14,4	36	**75**	18	99	62	**74**	31	28	20
4-16Ar-4-16Ar-K4	3	1,1/69/67	**1,1**	15,9	30	**69**	23	98	54	**67**	32	27	30
4K-16Ar-4-16Ar-K4	3	0,8/63/58	**0,8**	16,9	22	**63**	23	98	47	**58**	32	27	30
Pilkington Optitherm™ S3			ε = 0,037						Tyk: 4, 6, 8 og 10 mm				
4-10Kr-S(3)4	2	1,0/80/63	**1,0**	16,3	27	**80**	13	98	56	**63**	31	28	20
4-12Ar-S(3)4	2	1,3/80/63	**1,3**	15,1	27	**80**	13	98	56	**63**	31	28	20
4-16Ar-S(3)4	2	1,1/80/63	**1,1**	15,9	27	**80**	13	98	56	**63**	31	28	20
6-16Ar-S(3)4	2	1,1/79/59	**1,1**	15,9	24	**79**	13	97	53	**59**	32	28	25
6-16Ar-S(3)6,4L	2	1,1/77/59	**1,1**	15,9	2	**77**	12	96	47	**59**	33	28	30
4+30+4-16Ar-S(3)4	1+2	0,9/73/57	**0,9**	16,8	23	**73**	19	97	50	**57**	37	31	30
4-12Ar-4-12Ar-S(3)4	3	1,0/73/57	**1,0**	16,3	23	**73**	19	97	50	**57**	32	27	30
				,8	23	**73**	19	97	50	**57**	32	27	30
				,6	23	**73**	19	97	50	**57**	32	27	30
				,8	2	**72**	19	96	45	**57**	35	29	36
				,8	21	**72**	18	96	47	**54**	36	30	35
				,3	13	**72**	18	96	44	**51**	32	27	30
				,8	13	**72**	18	96	44	**51**	32	27	30
				,0	13	**72**	18	96	44	**51**	32	27	30
Pi									Tyk: 4 og 6 mm				
				,3	31	**71**	21	97	43	**49**	31	28	20
				,5	31	**71**	21	97	43	**49**	31	28	20
				,3	31	**71**	23	97	43	**49**	31	28	20
				,3	2	**68**	21	95	38	**46**	33	28	30
				,0	26	**65**	26	96	39	**46**	37	31	30
				,3	26	**65**	26	96	39	**46**	32	27	30
				,0	26	**65**	26	96	39	**46**	32	27	30
				,0	2	**64**	26	95	36	**46**	35	29	36
				,0	18	**57**	31	95	30	**36**	32	27	30
Pi													
				,4	17	**67**	20	98	44	**52**	37	31	30
4+30+K4-16Ar-S(3)4	1+2	0,7/67/56	**0,7**	17,4	17	**67**	21	98	44	**56**	37	31	30
Pilkington Optifloat™ Clear (klart floatglas)													
4	1	5,8/90/87	**5,8**	−1,8	65	**90**	8	99	85	**87**	29	26	10
4-16Ar-4	2	2,6/82/78	**2,6**	10,3	50	**82**	15	97	74	**78**	31	28	20
4-12Ar-4-12Ar-4	3	1,8/75/71	**1,8**	13,3	40	**75**	20	97	64	**71**	32	27	30

Forklaringer til tabelrubrikkerne findes på side 10-11.
Yderligere data og værdier for andre produktkombinationer finder du i Pilkington Spectrum.

Edit Material

Glas, U=0,9 Baunehøj

Heat Transmittance
Normal 0,57
Diffuse 0

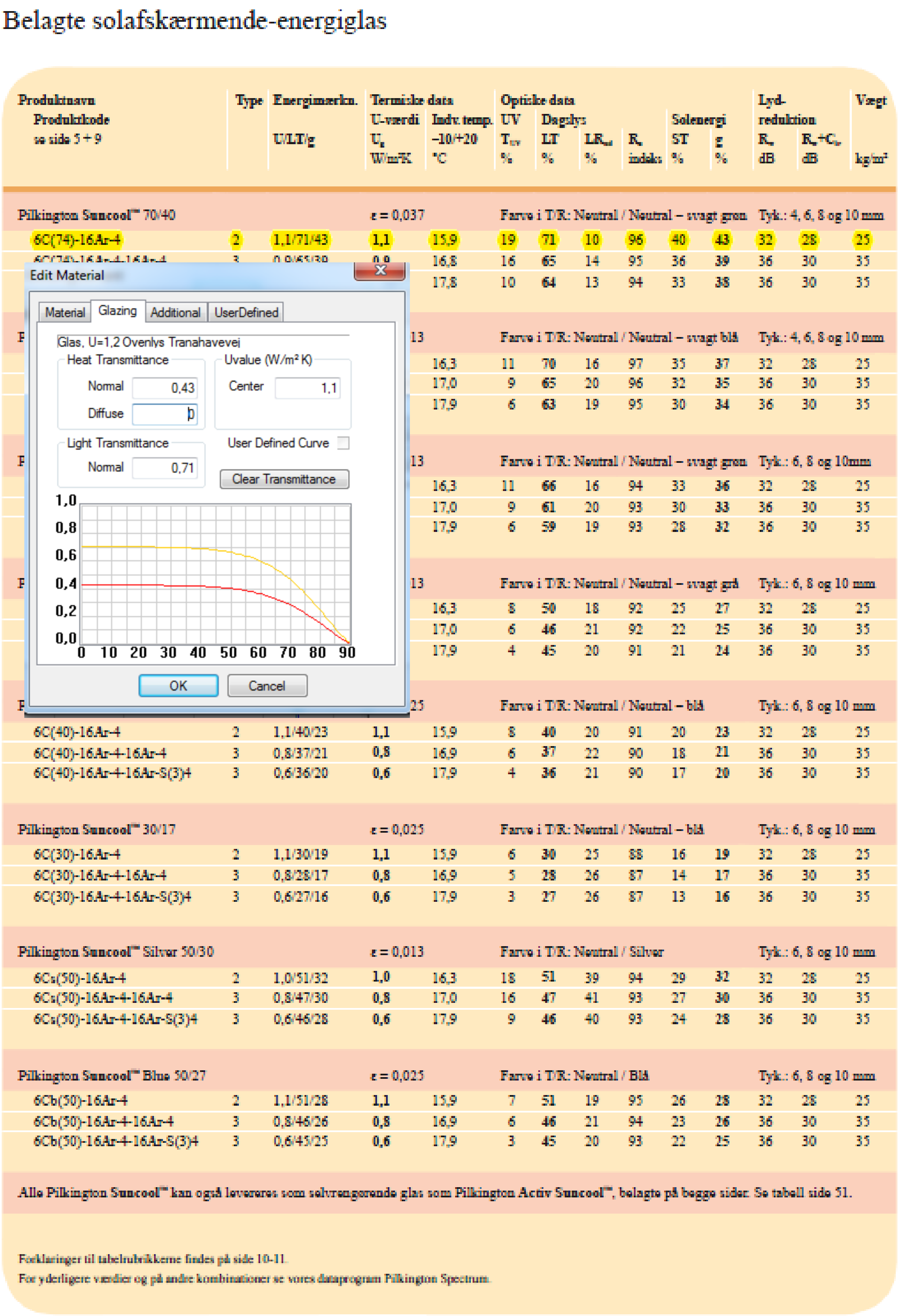
Uvalue (W/m² K)
Center 0,9

Light Transmittance
Normal 0,73

User Defined Curve ☐

Figure 1 - Facade window properties.

Skylights (Pilkington sunshading energy glass)



Belagte solafskærmende-energiglas

Produktnavn Produktkode se side 5 + 9	Type	Energimærkn. U/LT/g	Termiske data U-værdi U_g W/m²K	Indv. temp. −10/+20 °C	Optiske data UV T_{uv} %	Dagslys LT %	LR_{ud} %	R_a indeks	Solenergi ST %	g %	Lyd-reduktion R_w dB	R_w+C_{tr} dB	Vægt kg/m²
Pilkington Suncool™ 70/40			ε = 0,037		Farve i T/R: Neutral / Neutral – svagt grøn						Tyk.: 4, 6, 8 og 10 mm		
6C(74)-16Ar-4	2	1,1/71/43	1,1	15,9	19	71	10	96	40	43	32	28	25
6C(74)-16Ar-4-16Ar-4	3	0,9/65/39	0,9	16,8	16	65	14	95	36	39	36	30	35
				17,8	10	64	13	94	33	38	36	30	35
P			13		Farve i T/R: Neutral / Neutral – svagt blå						Tyk.: 4, 6, 8 og 10 mm		
				16,3	11	70	16	97	35	37	32	28	25
				17,0	9	65	20	96	32	35	36	30	35
				17,9	6	63	19	95	30	34	36	30	35
P			13		Farve i T/R: Neutral / Neutral – svagt grøn						Tyk.: 6, 8 og 10mm		
				16,3	11	66	16	94	33	36	32	28	25
				17,0	9	61	20	93	30	33	36	30	35
				17,9	6	59	19	93	28	32	36	30	35
P			13		Farve i T/R: Neutral / Neutral – svagt grå						Tyk.: 6, 8 og 10 mm		
				16,3	8	50	18	92	25	27	32	28	25
				17,0	6	46	21	92	22	25	36	30	35
				17,9	4	45	20	91	21	24	36	30	35
P			25		Farve i T/R: Neutral / Neutral – blå						Tyk.: 6, 8 og 10 mm		
6C(40)-16Ar-4	2	1,1/40/23	1,1	15,9	8	40	20	91	20	23	32	28	25
6C(40)-16Ar-4-16Ar-4	3	0,8/37/21	0,8	16,9	6	37	22	90	18	21	36	30	35
6C(40)-16Ar-4-16Ar-S(3)4	3	0,6/36/20	0,6	17,9	4	36	21	90	17	20	36	30	35
Pilkington Suncool™ 30/17			ε = 0,025		Farve i T/R: Neutral / Neutral – blå						Tyk.: 6, 8 og 10 mm		
6C(30)-16Ar-4	2	1,1/30/19	1,1	15,9	6	30	25	88	16	19	32	28	25
6C(30)-16Ar-4-16Ar-4	3	0,8/28/17	0,8	16,9	5	28	26	87	14	17	36	30	35
6C(30)-16Ar-4-16Ar-S(3)4	3	0,6/27/16	0,6	17,9	3	27	26	87	13	16	36	30	35
Pilkington Suncool™ Silver 50/30			ε = 0,013		Farve i T/R: Neutral / Silver						Tyk.: 6, 8 og 10 mm		
6Cs(50)-16Ar-4	2	1,0/51/32	1,0	16,3	18	51	39	94	29	32	32	28	25
6Cs(50)-16Ar-4-16Ar-4	3	0,8/47/30	0,8	17,0	16	47	41	93	27	30	36	30	35
6Cs(50)-16Ar-4-16Ar-S(3)4	3	0,6/46/28	0,6	17,9	9	46	40	93	24	28	36	30	35
Pilkington Suncool™ Blue 50/27			ε = 0,025		Farve i T/R: Neutral / Blå						Tyk.: 6, 8 og 10 mm		
6Cb(50)-16Ar-4	2	1,1/51/28	1,1	15,9	7	51	19	95	26	28	32	28	25
6Cb(50)-16Ar-4-16Ar-4	3	0,8/46/26	0,8	16,9	6	46	21	94	23	26	36	30	35
6Cb(50)-16Ar-4-16Ar-S(3)4	3	0,6/45/25	0,6	17,9	3	45	20	93	22	25	36	30	35

Alle Pilkington Suncool™ kan også leveres som selvrengørende glas som Pilkington Activ Suncool™, belagte på begge sider. Se tabell side 51.

Forklaringer til tabelrubrikkerne findes på side 10-11.
For yderligere værdier og på andre kombinationer se vores dataprogram Pilkington Spectrum.

Edit Material

Glas, U=1,2 Ovenlys Tranahavevej

Heat Transmittance
Normal 0,43
Diffuse 0

Uvalue (W/m² K)
Center 1,1

Light Transmittance
Normal 0,71

User Defined Curve ☐

Figure 2 - Skylights properties.

Appendix D - BIM ”State of the art”

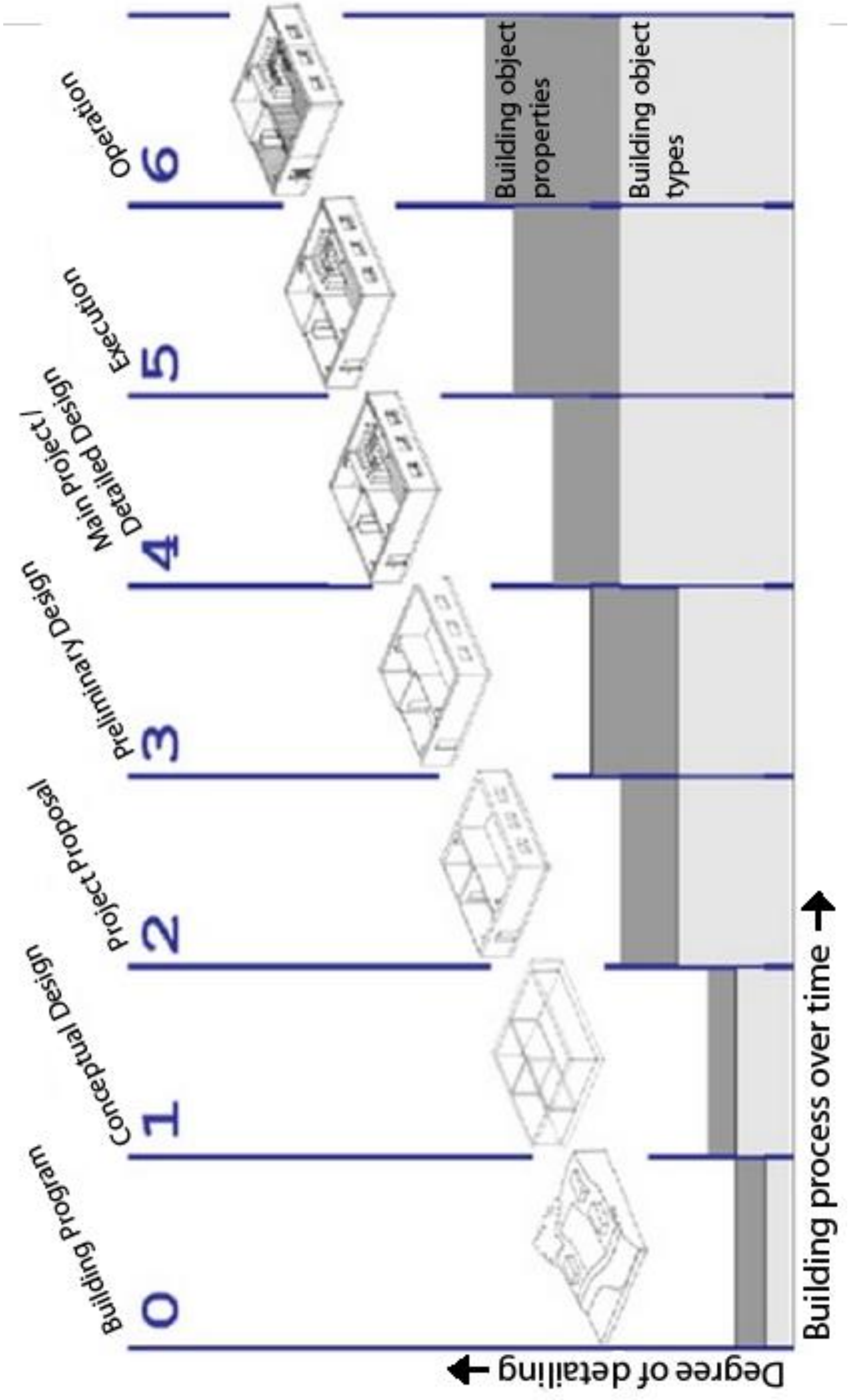


Figure 1 - Information levels of a building information model. Figure: [DDB]

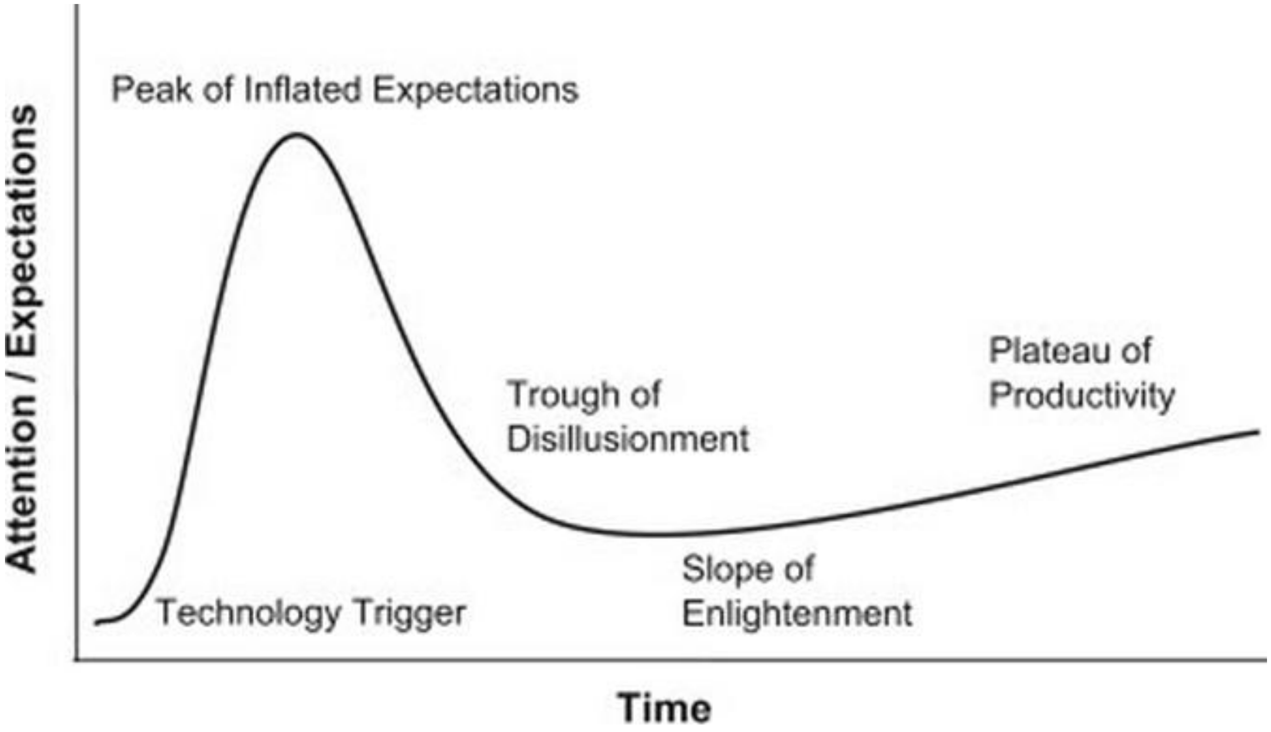


Figure 2 - The Gartner hype curve. Gartner is an information technology research and advisory company in Stamford. (Figure: [sciencedirect].

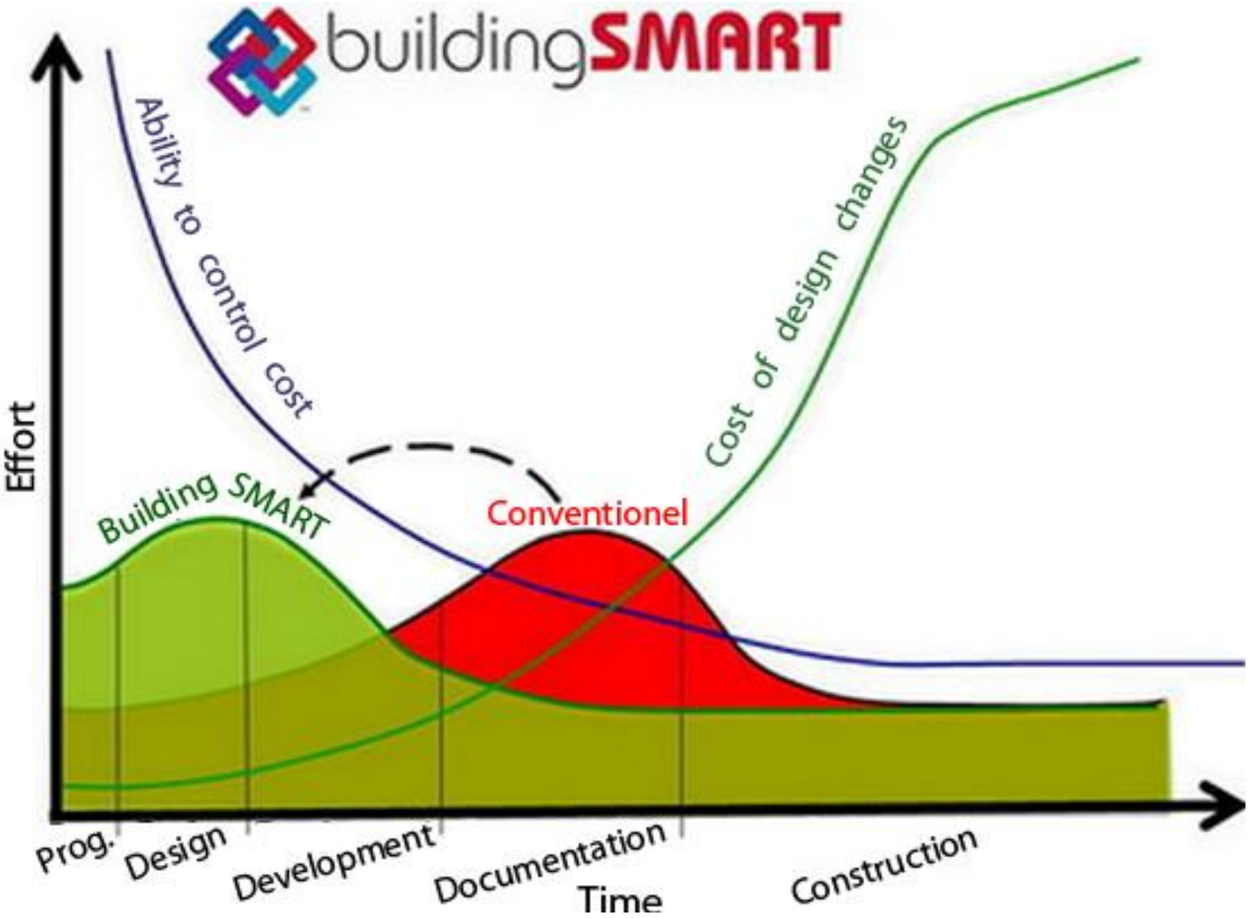


Figure 3 – MacLeamy Curve [BuildingSMART.com]

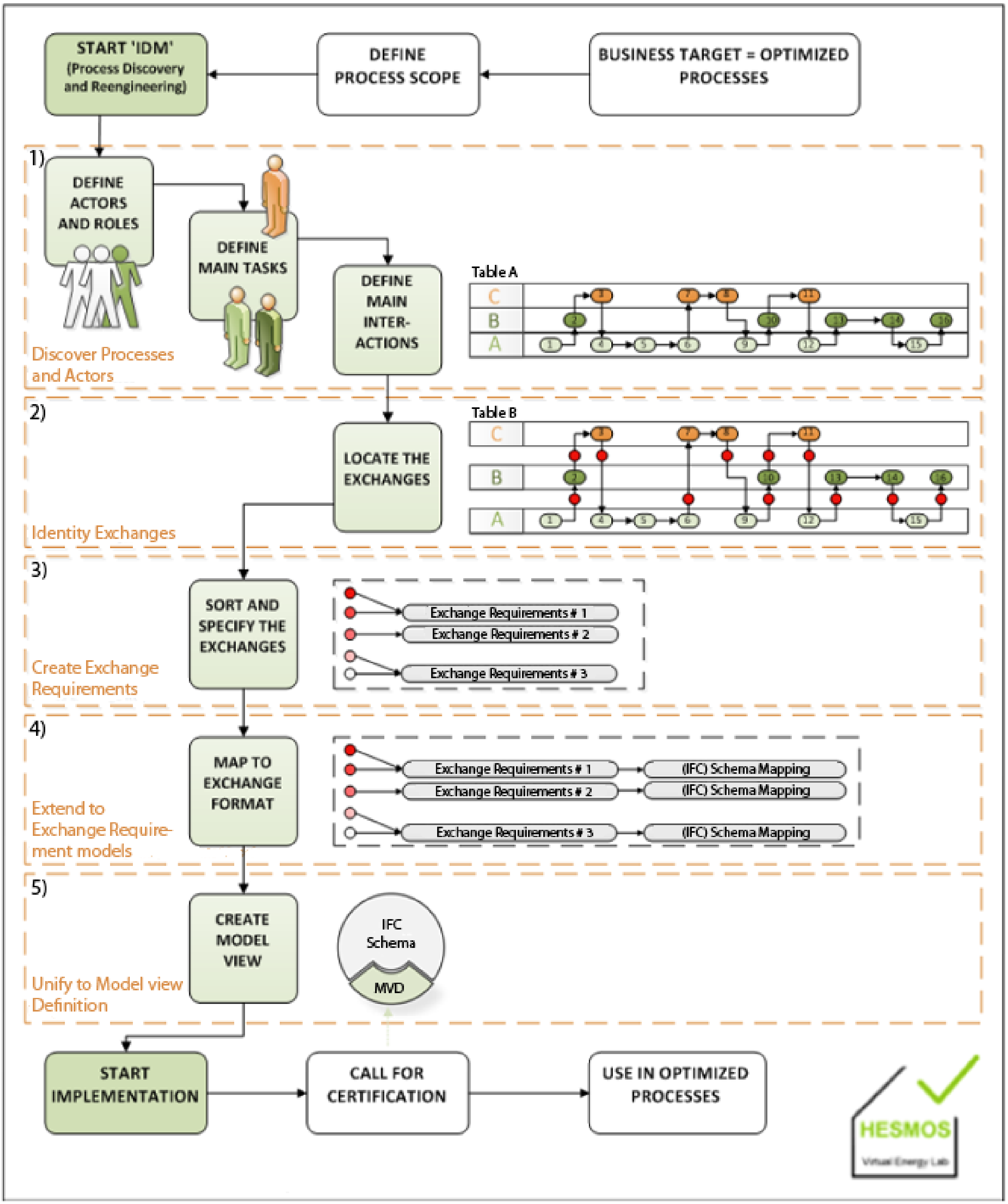


Figure 2- General process of Information Delivery Manual (IDM) (Figure: [HESMOS])

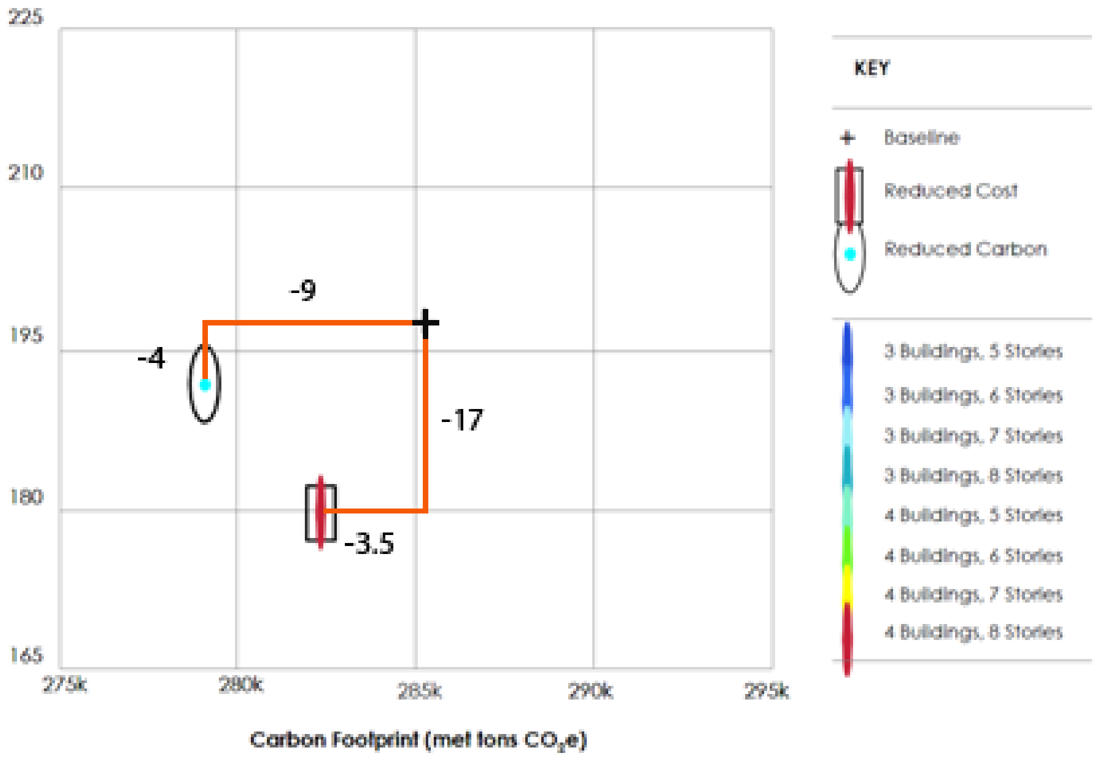


Figure 3 - Life-cycle cost vs. carbon footprint of the initial design (baseline), reduced costs (blue) and reduced carbon footprint (red). (Figure: [Stanford CIFE]).

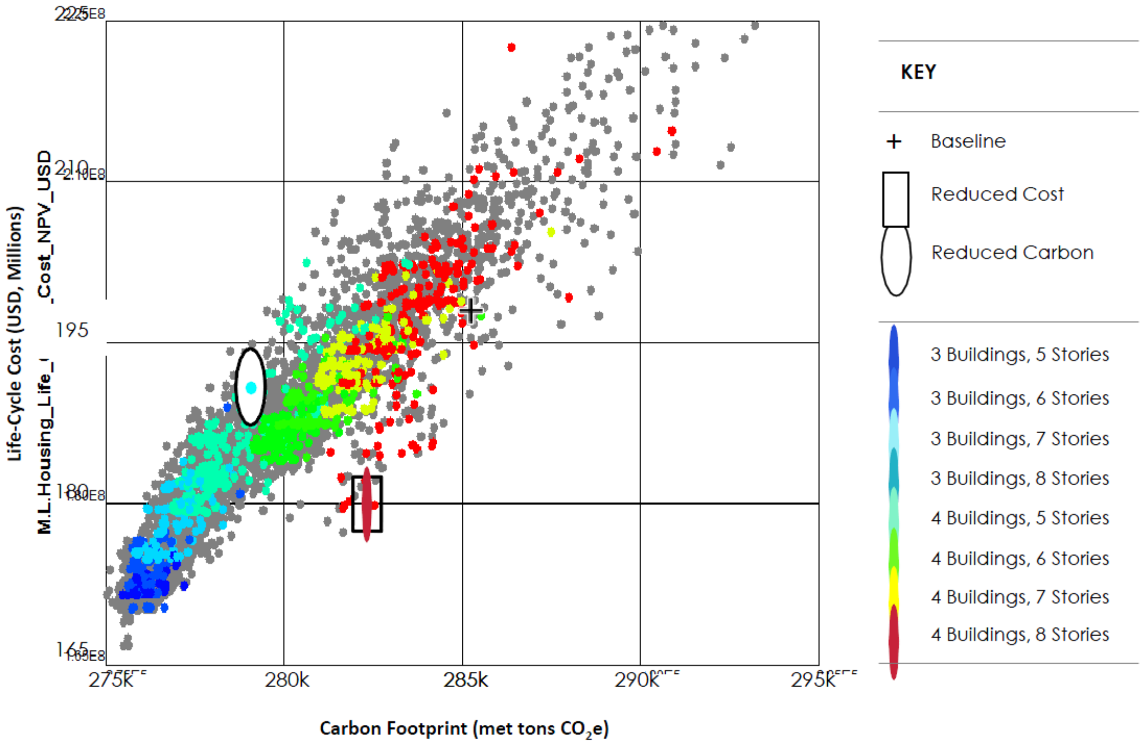


Figure3 - Plot of the 21.360 alternative scenarios simulated by a Cloud Network together with the baseline design and the two previously optimized scenarios. (Figure: [Stanford CIFE]).

Solibri Model Checker Report

Model Name	Simplified model
Checker	Daniel
Organization	DTU
Time	12/11/12 6:13 PM
Simplified model with modified skylights4	Time: 2012-12-11 16:48:48 Application: Autodesk Revit Architecture 2012 IFC: IFC2X3

BIM Validation	**Accepted**	**Rejected**	**Major**	**Normal**	**Minor**	**Comment**
Model Structure Check		X		x	x	
Model Hierarchy	OK					
Building Floors	OK					
Doors and Windows		X		x		
Door Opening Direction Definition	OK			x	x	
Components and Construction Types	OK			x		
Component Dimensions	OK			x		
Walls Must Have at Least Minimal Dimensions	OK			x		
Door Openings Must Have at Least Minimal Size	OK					
Window Openings Must Have at Least Minimal Size	OK					
Slab Dimensions Must Be Within Sensible Bounds	-					
Roof Dimensions Must Be Within Sensible Bounds	OK					
Column Dimensions Must Be Within Sensible	-					
Beam Dimensions Must Be Within Sensible Bounds	-					
Wall Opening Distances	OK					
Floor Heights	OK					
Clearance in Front of		X	x			
Clearance in Front of Windows		X	x			
Clearance in Front of Doors	OK					
Deficiency Detection		X	x	x	x	
Required Components		X		x		
Unallocated Areas	OK					
Components Below and Above		X	x	x	x	
Components Below and Above Columns	-					
Components Below and Above Beams	-					
Components Below and Above Walls		X	x	x	x	
Space Check			x	x	x	
The Model Should Have Spaces	OK					
Space Properties			x	x		
Spaces Must Have a Name				x		
Spaces Should Have Usage Classification				x		
Spaces Must Have Unique Identifier			x	x		
Space Dimensions Must Be Within Sensible Bounds	OK					
Space Elevation Should Be Within Sensible Bounds	OK					
Spaces Must Have Enough Window Area						
Space Location			x		x	
Space Validation			x		x	
Space Intersections	OK					
Spaces in Same Building Storey Must Have Same	OK					
Space Group Analysis		X		x	x	
Spaces Must Be Included in Space Groups	OK			x		
External Wall Validation		X		x		
Key Figure Analysis	OK			x	x	

Intersection Checking		X	x	x	x	
Intersections - Same Kind of Components		X	x	x	x	
Wall - Wall Intersections		X	x		x	
Slab - Slab Intersections	-					
Roof - Roof Intersections		X	x	x		
Beam - Beam Intersections	-					
Column - Column Intersections	-					
Door - Door Intersections	OK					
Window - Window Intersections	OK					
Stair - Stair Intersections	-					
Suspended Ceiling - Suspended Ceiling	OK					
Railing - Railing Intersections	-					
Ramp - Ramp Intersections	-					
Intersections - Different Kind of Components		X	x	x	x	
Door Intersections		X	x			
Window Intersections		X	x			
Column Intersections	-					
Beam Intersections	-					
Stair Intersections	-					
Railing Intersections	-					
Suspended Ceiling Intersections	OK					
Wall Intersections		X	x	x	x	
Slab Intersections	-					
Roof Intersections	-					
Intersections of Furniture and Other Objects	-					
Object Intersections	-					
Doors/Windows and Objects	-					
Objects and Other Components	-					

Component	Type [mm]	Total Component Volume [cu ft]	Intersection Volume [cu ft]	Percentage
Wall	Basic Wall:Glas	41,91	0,12	0,28%
Wall	Basic Wall:Ydervæg 500	4921,62	13,65	0,28%
Wall	Basic Wall:Beton 100	1227,36	1,49	0,12%
Wall	Basic Wall:Beton 150	2351,15	4,23	0,18%
Wall	Basic Wall:Gips 95	430,86	0,18	0,04%
Wall	Basic Wall:Pergola 100	191,25	0,01	0,00%

Component	Type [mm]	Total Component Volume [m^3]	Intersection Volume [m^3]	Percentage
Wall	Basic Wall:Glas	1,19	0,00	0,28%
Wall	Basic Wall:Ydervæg 500	139,36	0,39	0,28%
Wall	Basic Wall:Beton 100	34,75	0,04	0,12%
Wall	Basic Wall:Beton 150	66,58	0,12	0,18%
Wall	Basic Wall:Gips 95	12,20	0,01	0,04%
Wall	Basic Wall:Pergola 100	5,42	0,00	0,00%

Floor	Height	Gross Area	Net Area	Net Area Ratio
0 - Fundament	1,97			
1 - Stuenplan 3.1m	9,84	10520,32	9248,03	88,00%
2 - Tagkant	9,91			
Total	21,72	10520,32	9248,03	88,00%

Floor	Wall Area	Empty Area Ratio	Volume	External Wall Area
0 - Fundament				
1 - Stuenplan 3.1m	1269,71	0,00%	103546,5	5244,3
2 - Tagkant				
Total	1269,71	0,00%	103546,5	5244,3

Floor	External Wall Bottom Area	External Wall Area/Gross Area	Gross Area - External Wall Area	Window Area	Window Area Ratio
0 - Fundament					
1 - Stuenplan 3.1m	860,8	0,5	9682,8	1317,8	25,00%
2 - Tagkant					
Total		0,5		1317,8	25,00%

Component	Construction Type	Count
Door	D7:D7.5 1510mm uligfløjet 11+4	2
Door	Indv. dør - plade dobbelt håndtag:10M x21 EI2 30-C 2 (håndtag øverst)	20
Door	Indv. dør - plade dobbelt håndtag:9M x21 EI2 30-C	2
Door	Indv. dør - plade dobbelt håndtag:9M x21 EI2 30-C 2 (håndtag øverst)	5
Door	Indv. dør - plade:10M x21	8
Door	Indv. dør - plade:9M x21	6
Door	Skydedør integreret:Skydedør integreret 2	3
Roof	Basic Roof:870 mm tag	12
Roof	Basic Roof:Ovenlys opbygning	4
Space	arbejdsniche	1
Space	boilerrum	1
Space	depot	3
Space	gang	1
Space	garderobe	6
Space	garderobe / kopi	1
Space	grovgarderobe	1
Space	grupperum	6
Space	kontor	1
Space	køkken	1
Space	pers. wc	1
Space	personale rum	1
Space	Pædagogisk køkken	1
Space	Room	2
Space	samtalerum	1
Space	toilet	6
Space	tørrerum	2
Space	ude wc	1
Space	Undefined	3
Space	vaskeri /rengøring	1
Space	værkstedsrum	1
Wall	Basic Wall:15x15 fliser	1
Wall	Basic Wall:Beton 100 mm	27
Wall	Basic Wall:Beton 150 mm	26
Wall	Basic Wall:Gips 95 mm	18
Wall	Basic Wall:Glas	6
Wall	Basic Wall:Pergola 100 mm	12
Wall	Basic Wall:Ydervæg 195 på tag	6
Wall	Basic Wall:Ydervæg 500 mm	17
Window	ovenlys 3 felter:2850x6000	3
Window	ovenlys 5 felter:2950x1000mm	6
Window	ovenlys1felt:1000x1000	8
Window	V1.1:1200 x1200 mm	1
Window	V1.1:1300 x1300 mm	1
Window	V1.1:1400 x1400 mm	9
Window	V1.1:1500 x1500 mm	3
Window	V1.1:1700 x1700 mm	1
Window	V1.1:1745 x 2100 mm	8
Window	V1.1:550 x 550 mm	6
Window	V1.1:700 x 700 mm	6
Window	V1.1:900 x 900 mm	2
Window	V2.2:1700 x 2155 mm	1
Window	V2.2:1700x2505 mm	6
Window	VD 1.1:1100x2100mm	8
Window	VD 1.1:910 x 2100 mm	4
Window	VD 2.1:1600x2100mm	2
Window	Vindue_Indvendigt:indvendigt 1400x1000	1
Window	Vindue_Indvendigt:indvendigt 1800x1800	6

Window	Vindue_Indvendigt:indvendigt 2100x1000	1
Window	Vindue_Indvendigt:indvendigt 2100x1435	2
Window	Vindue_Indvendigt:indvendigt 2100x290	1
Window	Vindue_Indvendigt:indvendigt 2100x300	6
Window	Vindue_Indvendigt:indvendigt 2100x400	1
Window	Vindue_Indvendigt:indvendigt 2100x710	1
Window	Vindue_Indvendigt:indvendigt 900x900	7

Component	Construction Type	Count
Space	arbejdsniche	1
Space	boilerrum	1
Space	depot	3
Space	gang	1
Space	garderobe	6
Space	garderobe / kopi	1
Space	grovgarderobe	1
Space	grupperum	6
Space	kontor	1
Space	køkken	1
Space	pers. wc	1
Space	personale rum	1
Space	Pædagogisk køkken	1
Space	Room	2
Space	samtalerum	1
Space	toilet	6
Space	tørrerum	2
Space	ude wc	1
Space	Undefined	3
Space	vaskeri /rengøring	1
Space	værkstedsrum	1

SOLIBRI

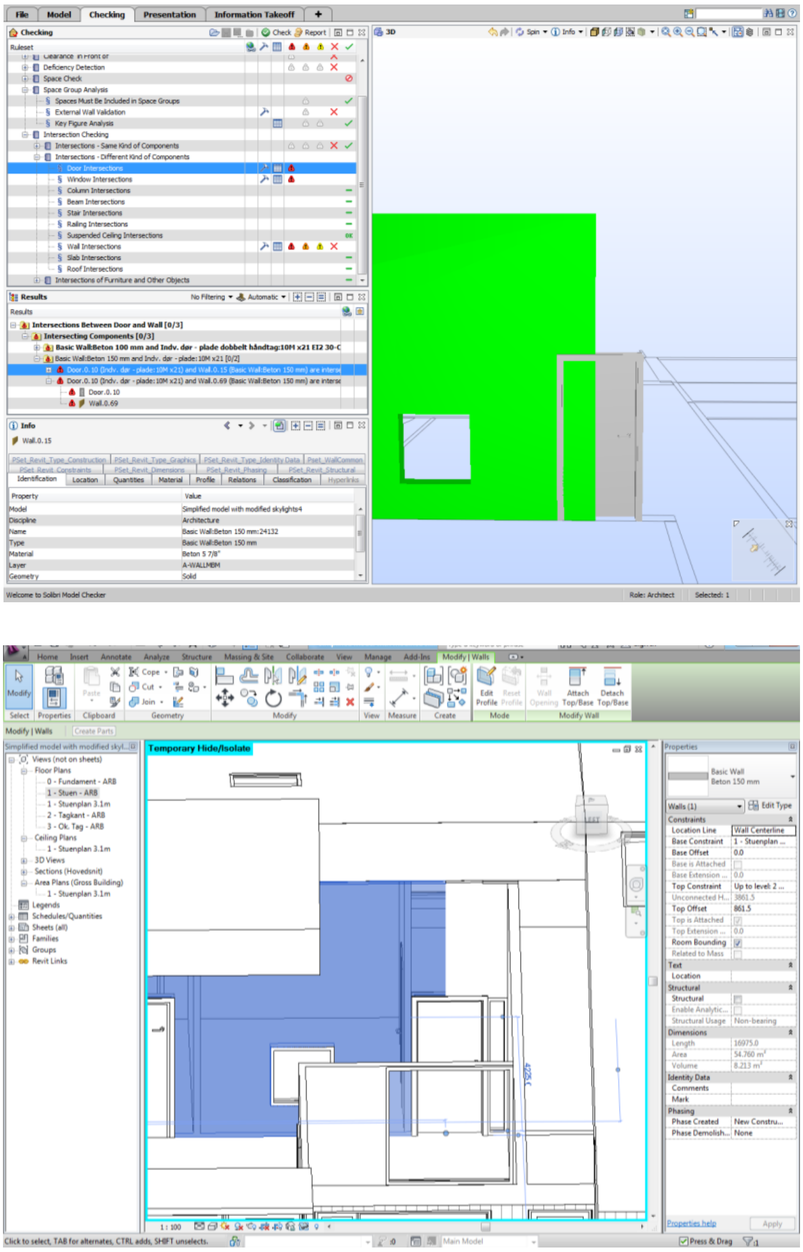
Quantities

Model Name	Simplified model
User	Daniel
Organization	DTU
Date	December 12, 2012
Simplified model with modified skylights4	Date: 2012-12-11 16:48:48 Application: Autodesk Revit Architecture 2012 IFC: IFC2X3

Building Element Type	Type	Net Area	Length	Volume	Count
A2020 Basement Walls	Basic Wall:15x15 fliser	27,5	6,2	0,9	1
A2020 Basement Walls	Basic Wall:Beton 100 mm	3732,0	371,5	1227,4	27
A2020 Basement Walls	Basic Wall:Beton 150 mm	4743,7	482,5	2351,2	26
A2020 Basement Walls	Basic Wall:Gips 95 mm	1374,7	193,1	430,9	18
A2020 Basement Walls	Basic Wall:Glas	319,7	61,6	41,9	6
A2020 Basement Walls	Basic Wall:Pergola 100 mm	582,3	65,4	191,3	12
A2020 Basement Walls	Basic Wall:Ydervæg 195 på tag	56,6	34,9	36,2	6
A2020 Basement Walls	Basic Wall:Ydervæg 500 mm	3037,8	514,4	4921,6	17
B1020 Roof Construction	Basic Roof:870 mm tag	13624,7		39843,1	12
B1020 Roof Construction	Basic Roof:Ovenlys opbygning	1547,8		1777,3	4
B2020 Exterior Windows	V1.1:1200 x1200 mm	15,5		24,9	1
B2020 Exterior Windows	V1.1:1300 x1300 mm	18,2		29,3	1
B2020 Exterior Windows	V1.1:1400 x1400 mm	189,9		306,1	9
B2020 Exterior Windows	V1.1:1500 x1500 mm	72,7		117,3	3
B2020 Exterior Windows	V1.1:1700 x1700 mm	31,1		50,3	1
B2020 Exterior Windows	V1.1:1745 x 2100 mm	315,6		511,7	8
B2020 Exterior Windows	V1.1:550 x 550 mm	19,5		23,0	6
B2020 Exterior Windows	V1.1:700 x 700 mm	31,7		44,8	6
B2020 Exterior Windows	V1.1:900 x 900 mm	17,4		27,8	2
B2020 Exterior Windows	V2.2:1700 x 2155 mm	39,4		63,8	1
B2020 Exterior Windows	V2.2:1700x2505 mm	275,0		227,4	6
B2020 Exterior Windows	VD 1.1:1100x2100mm	198,9		36,1	8
B2020 Exterior Windows	VD 1.1:910 x 2100 mm	82,3		16,0	4
B2020 Exterior Windows	VD 2.1:1600x2100mm	72,3		117,3	2
B2020 Exterior Windows	Vindue_Indvendigt 1400x1000	15,1		1,6	1
B2020 Exterior Windows	Vindue_Indvendigt 1800x1800	209,3		13,2	6
B2020 Exterior Windows	Vindue_Indvendigt 2100x1000	22,2		1,1	1
B2020 Exterior Windows	Vindue_Indvendigt 2100x1435	64,9		2,9	2
B2020 Exterior Windows	Vindue_Indvendigt 2100x290	6,6		0,5	1
B2020 Exterior Windows	Vindue_Indvendigt 2100x300	40,7		8,2	6

B2020 Exterior Windows	Vindue_Indvendigt 2100x400	9,0	0,6	1
B2020 Exterior Windows	Vindue_Indvendigt 2100x710	16,1	0,8	1
B2020 Exterior Windows	Vindue_Indvendigt 900x900	61,0	7,9	7
B2020 Exterior Windows	ovenlys 3 felter:2850x6000	107,0	19,5	3
B2020 Exterior Windows	ovenlys 5 felter:2950x1000mm	94,5	134,4	6
B2020 Exterior Windows	ovenlys1felt:1000x1000	26,6	11,0	8
C3020 Floor Finishes	Compound Ceiling:Pergola top	916,6	131,5	7
Unclassified	D7:D7.5 1510mm uligfløjet 11+4	73,2	22,7	2
Unclassified	Indv. dør - plade dobbelt håndtag: 10M x21 EI2 30-C 2 (håndtag øverst)	454,5	181,3	20
Unclassified	Indv. dør - plade dobbelt håndtag: 9M x21 EI2 30-C	41,8	16,6	2
Unclassified	Indv. dør - plade dobbelt håndtag: 9M x21 EI2 30-C 2 (håndtag øverst)	104,5	41,6	5
Unclassified	Indv. dør - plade:10M x21	174,3	81,1	8
Unclassified	Indv. dør - plade:9M x21	125,4	46,5	6
Unclassified	Skydedør integreret: Skydedør integreret 2	96,4	1,5	3

Appendix F - Comparason of issues found in Solibri and Revit.



Results

- Intersections Between Door and Wall [0/3]
  - Intersecting Components [0/3]
    - Basic Wall:Beton 100 mm and Indv. dør - plade dobbelt håndtag:10M x21 EI2 30-C
    - Basic Wall:Beton 150 mm and Indv. dør - plade:10M x21 [0/2]
      - Door.0.10 (Indv. dør - plade:10M x21) and Wall.0.15 (Basic Wall:Beton 150 mm) are interse
      - Door.0.10 (Indv. dør - plade:10M x21) and Wall.0.69 (Basic Wall:Beton 150 mm) are interse
        - Door.0.10
        - Wall.0.69

Info

Wall.0.15

Property	Value
Model	Simplified model with modified skylights4
Discipline	Architecture
Name	Basic Wall:Beton 150 mm:24132
Type	Basic Wall:Beton 150 mm
Material	Beton 5 7/8"
Layer	A-WALLMBM
Geometry	Solid

Welcome to Solibri Model Checker

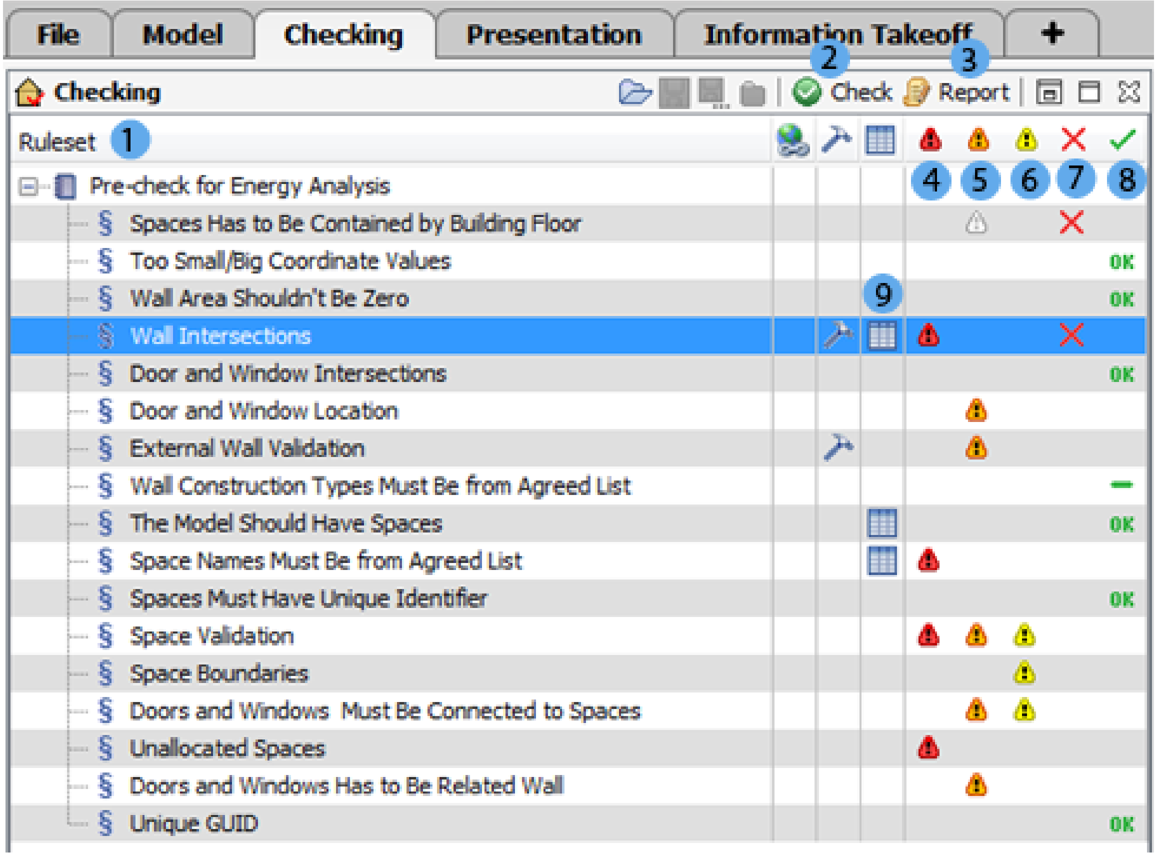
Properties

Basic Wall
Beton 150 mm

Walls (1)

Constraints	
Location Line	Wall Centerline
Base Constraint	1 - Stuenplan ...
Base Offset	0.0
Base is Attached	☐
Base Extension ...	0.0
Top Constraint	Up to level: 2 ...
Unconnected H...	3861.5
Top Offset	861.5
Top is Attached	☑
Top Extension ...	0.0
Room Bounding	☑
Related to Mass	☐
Text	
Location	
Structural	
Structural	☐
Enable Analytic...	☐
Structural Usage	Non-bearing
Dimensions	
Length	16975.0
Area	54.760 m²
Volume	8.213 m³
Identity Data	
Comments	
Mark	
Phasing	
Phase Created	New Constru...
Phase Demolish...	None

Figure 1 – The two figures above depict the same wall/door intersection in Solibri and Revit respectively. In Solibri it seems that the wall goes directly through the door, but in Revit it can be seen that the wall is correctly cut around the door. This is one example of misleading/false information provided in Solibri through its model check and does not have to be corrected by the design team.



Ruleset				⚠	⚠	⚠	✗	✓
Pre-check for Energy Analysis								
§ Spaces Has to Be Contained by Building Floor					⚠		✗	
§ Too Small/Big Coordinate Values								OK
§ Wall Area Shouldn't Be Zero								OK
§ Wall Intersections		🔨	▦	⚠			✗	
§ Door and Window Intersections								OK
§ Door and Window Location					⚠			
§ External Wall Validation		🔨			⚠			
§ Wall Construction Types Must Be from Agreed List								–
§ The Model Should Have Spaces			▦					OK
§ Space Names Must Be from Agreed List			▦	⚠				
§ Spaces Must Have Unique Identifier								OK
§ Space Validation				⚠	⚠	⚠		
§ Space Boundaries						⚠		
§ Doors and Windows Must Be Connected to Spaces					⚠	⚠		
§ Unallocated Spaces				⚠				
§ Doors and Windows Has to Be Related Wall					⚠			
§ Unique GUID								OK

Figure 2 – The same example of the model checking module in Solibri. The blue circles explain important functions of the program. 1) The selected ruleset (energy analysis), 2) Check start, 3) Print of report to Excel, 4) Severity level high, 5) Severity level moderate, 6) Severity level low, 7) not accepted issue, 8) accepted issue, 9) Rulereport. (See larger image in appendix F).

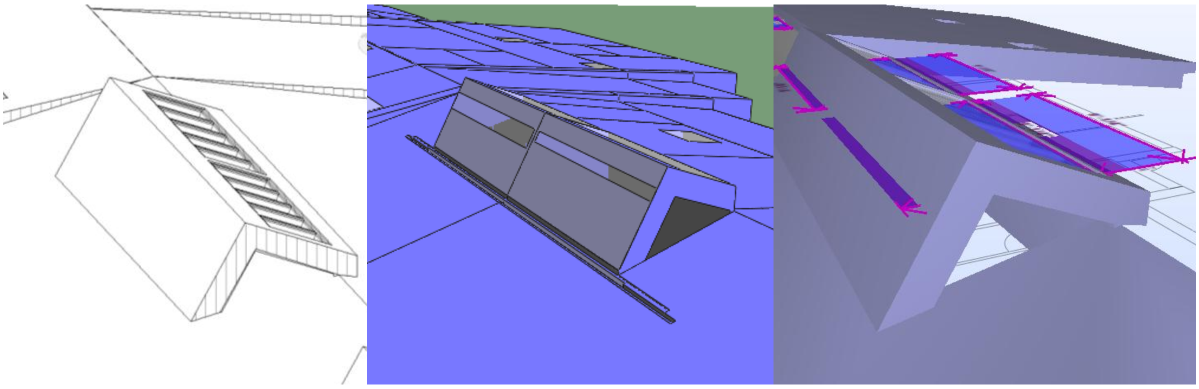


Figure 3 – Skylight construction illustrations. Left: the skylight construction in Revit. Middle: the skylight construction converted to gbXML file. Right: the skylight construction seen in Solibri where the program illustrate that the skylight family are somehow colliding with the skylight construction even though this is not visible in neither Revit nor the IES plug-in.

Be10 model: Tranehavevej_Be10_41,5kWh Date 20.02.2013 12.10

Tranehavevej Børneinstitution

The building

Building type	Other
Rotation	320,0 deg
Area of heated floor	977,0 m²
Area existing / other usage	0,0 m²
Heat capacity	120,0 Wh/K m²
Normal usage time	50 hours/week
Usage time, start at - end at, time	7 - 17

Calculation rules

Calculation rules	BR: Actual conditions
Suplement to energy frame	1,3 kWh/m² år

Heat supply and cooling

Basic heat supply	District heating
Electric panels	No
Wood stoves, gas radiators etc.	No
Solar heating plant	No
Heat pumps	No
Solar cells	Yes
Wind mills	No
Mechanical cooling	No

Room temperatures, set points

Heating	20,0 °C
Wanted	23,0 °C
Natural ventilation	24,0 °C
Mechanical cooling	25,0 °C
Heating store	15,0 °C

Dimensioning temperatures

Room temp.	20,0 °C
Outdoor temp.	-12,0 °C
Room temp. store	15,0 °C

External walls, roofs and floors					
Building component	Area (m²)	U (W/m²K)	b	Dim.Inside (C)	Dim.Outside (C)
Facade Nord	9,4	0,10	1,000		
Facade Syd	63,8	0,10	1,000		
Facade Vest	38,1	0,10	1,000		
Facade Øst	116,1	0,10	1,000		
Terrændæk	977,0	0,10	1,000	30	10
Tag	945,5	0,10	1,000		
Vægge i nord mod uopvarmet liggehal (fra CAD)	55,1	0,10	0,700		
Opgybning ovenlys	57,5	0,14	1,000		
Ialt	2262,5	-	-	-	-

Foundations etc.					
Building component	l (m)	Loss (W/mK)	b	Dim.Inside (C)	Dim.Outside (C)
Vinduer og døre (opgørelse - dobbelt ved tilstødende vinduer)	258,8	0,01	1,000		
Ovenlys øst + vest	108,5	0,10	1,000		
Fundament	156,3	0,10	1,300	30	
Ialt	523,6	-	-	-	-

Windows and outer doors												
Building component	Number	Orient	Inclination	Area (m²)	U (W/m²K)	b	Ff (-)	g (-)	Shading	Fc (-)	Dim.Inside (C)	Dim.Outside (C)
Vinduer i nord facade	1	n	90,0	5,4	0,90	1,000	0,80	0,57	Default	0,20		
Vinduer i øst facade	1	ø	90,0	23,9	0,90	1,000	0,80	0,57	Default	0,20		
Vinduer i syd facade	1	s	90,0	7,8	0,90	1,000	0,80	0,57	Default	0,20		
Ovenlys øst	1	ø	12,0	25,7	1,20	1,000	0,80	0,57	Default	0,70		
Ovenlys vest	1	v	12,0	17,1	1,20	1,000	0,80	0,57	Default	0,70		
vinduer fælles espalier højre	2	v	90,0	3,9	0,90	1,000	0,80	0,57	GR udhæng m. højre ved fælles espalier	0,20		
Vinduer m. udhæng, fællesrum	2	v	90,0	3,9	0,90	1,000	0,80	0,63	Fællesrum, vest udhæng	0,20		
vindue, vindfanf	1	s	90,0	1,9	0,90	1,000	0,80	0,63	Skygge fra bygning, syd højre	0,20		

Vinduer m. udhæng mod syd & nord	2	v	90,0	3,9	0,90	1,000	0,80	0,63	GR længst mod syd/nord, vest udhæng top + højre, venstre	0,20		
Vinduer fælles espalier venstre	2	v	90,0	3,9	0,90	1,000	0,80	0,63	GR udhæng m. venstre ved fælles espalier	0,20		
Døre i vest ved espalier	7	v	90,0	2,3	0,90	1,000	0,80	0,63	Skygge døre ved espalier vest	1,00		
Resten af dørene	4	v	90,0	1,9	0,90	1,000	0,80	0,63	Default	1,00		
Vinduer ved køkken	3	v	90,0	2,5	0,90	1,000	0,80	0,63	Default	0,20		
GR Vinduer ved siden af udhæng venstre	2	v	90,0	4,4	0,90	1,000	0,80	0,63	GR ved siden af udhæng venstre	0,20		
GR Vinduer ved siden af udhæng højre	2	v	90,0	4,4	0,90	1,000	0,80	0,63	GR ved siden af udhæng højre	0,20		
GR Vinduer ved siden af værksted	1	v	90,0	4,4	0,90	1,000	0,80	0,63	GR ved siden af værksted	0,20		
GR Vinduer ved siden af WC	1	v	90,0	4,4	0,90	1,000	0,80	0,63	GR ved siden af ude WC	0,20		
Ialt	34	-	-	170,7	-	-	-	-	-	-	-	-

Shading					
Description	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening (%)
Default	15	0	0	0	10
Fællesrum, vest udhæng	15	70	38	42	10
Skygge fra bygning, syd venstre	15	0	80	0	10
Skygge fra bygning, syd højre	15	0	0	80	10
GR længst mod syd/nord, vest udhæng top + højre, venstre	15	40	47	47	10
GR udhæng m. venstre ved fælles espalier	15	40	47	0	10

GR udhæng m. højre ved fælles espalier	15	40	0	47	10
GR ved siden af udhæng venstre	15	0	30	0	10
GR ved siden af udhæng højre	15	0	0	30	10
GR ved siden af værksted	15	0	66	30	10
GR ved siden af ude WC	15	0	47	75	10
Skygge fra bygning, nord venstre	15	0	80	0	10
Skygge fra bygning, nord højre	15	0	0	80	10
Skygge døre ved espalier vest	15	40	47	47	10

Ventilation

Zone	Area (m²)	Fo, -	qm (l/s m²), Winter	n vgv (-)	ti (°C)	El-HC	qn (l/s m²), Winter	qi,n (l/s m²), Winter	SEL (kJ/m³)	qm,s (l/s m²), Summer	qn,s (l/s m²), Summer	qm,n (l/s m²), Night	qn,n (l/s m²), Night
Grupperum børneh./vuggest.	264,0	1,00	1,60	0,85	18,0	No	0,10	0,06	1,3	2,00	1,80	0,10	0,06
Kontor/personalerum/samtalerum	65,3	1,00	0,80	0,85	18,0	No	0,10	0,06	1,3	2,00	1,50	0,10	0,06
Køkken, pæd	22,0	1,00	0,80	0,85	18,0	No	0,10	0,06	1,3	2,00	0,80	0,10	0,06
Toilet/puslerum	103,0	1,00	0,80	0,85	18,0	No	0,10	0,06	1,3	2,00	0,70	0,10	0,06
Garderobe/tørrerum/vindfang	298,0	1,00	0,80	0,85	18,0	No	0,10	0,06	1,3	2,00	1,20	0,10	0,06
Andet	174,7	1,00	0,80	0,85	18,0	No	0,10	0,06	1,3	2,00	0,70	0,10	0,06
Køkken, prod	50,0	1,00	0,80	0,65	18,0	No	0,10	0,06	1,3	2,00	1,60	0,10	0,06

Internal heat supply

Zone	Area (m²)	Persons (W/m²)	App. (W/m²)	App,night (W/m²)
Køkken	50	4,0	6,0	0,0
Resten af huset	927	4,0	6,0	0,0

Lighting

Zone	Area (m²)	General (W/m²)	General (W/m²)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m²)	Other (W/m²)	Stand-by (W/m²)	Night (W/m²)
Køkken (areal ifølge tegninger)	77,4	0,5	5,0	200	2,00	K	0,80	0,0	0,0	0,0	0,0
Grupperum børnehave/vuggestue	283,2	0,5	5,0	200	2,00	K	0,90	0,0	0,0	0,0	0,0
toilet/puslerum	102,5	0,5	5,0	200	2,00	K	0,80	0,0	0,0	0,0	0,0
Vindfang/grovgarderobe/tørrerum	298,1	0,5	5,0	200	1,00	K	0,80	0,0	0,0	0,0	0,0
Personalerum/samtale/arbejdsrum	65,3	0,5	5,0	200	2,00	K	0,80	0,0	0,0	0,0	0,0
Andet	150,5	0,5	5,0	200	1,00	U	0,70	0,0	0,0	0,0	0,0

Other el. consumption	
Outdoor lighting	0,0 W
Spec. apparatus, during service	0,0 W
Spec. apparatus, always	0,0 W

Basement car parkings etc.

Zone	Area (m²)	General (W/m²)	General (W/m²)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m²)	Other (W/m²)	Stand-by (W/m²)	Night (W/m²)

Mechanical cooling	
Description	Mekanisk køling
Share of floor area	0
El-demand	0,00 kWh-el/kWh-cool
Heat-demand	0,00 kWh-heat/kWh-cool
Load factor	1,2
Heat capacity phase shift (cooling)	0 Wh/m²
Increase factor	1,50
Documentation	

Heat distribution plant

Composition and temperature

Supply pipe temperature	70,0 °C	
Return pipe temperature	40,0 °C	
Type of plant	2-string	Anlægstype

Pumps

Pump type	Description	Number	Pnom	Fp
Constant service all year		0	0,0 W	0,00
Constant service during heating season	Opvarmningspumpe	1	100,0 W	0,40
Constant service during heating season	Bl. sløjfe	3	40,0 W	0,40

Heating pipes

Pipe lengths in supply and return	l (m)	Loss (W/mK)	b	Outdoor comp (J/N)	Unused summer (J/N)
Rørfordeling til gulvvarme	0,0	0,00	1,000	N	N

Domestic hot water	
Description	Varmt brugsvand

Hot-water consumption, average for the building	100,0 litre/year per m² of floor area
Domestic hot water temp.	55,0 °C

Hot-water tank

Description	Ny varmtvandsbeholder
Number of hot-water containers	1,0
Tank volume	800,0 liter
Supply temperature from central heating	70,0 °C
El. heating of DHW	No
Solar heat tank with heating coil	No
Heat loss from hot-water tank	1,8 W/K
Temp. factor for setup room	0,0

Charging pump

Effect	0,0 W
Controled	No
Charge effect	0,0 kW

Heat loss from connector pipe to DHW tank

Length	Loss	b	Description
6,0 m	0,2 W/K	0,00	

Cirkulating pump for DHW

Description	PumpCirc
Number	1,0
Effect	25,0 W
Number	0,0
Effect	0,0 W
Reduction factor	0,40 W
El. tracing of discharge water pipe	No

Domestic hot water discharge pipes

Pipe lengths in supply and return	l (m)	Loss (W/mK)	b
	80,0	0,17	0,000

Water heaters

Electric water heater

Description	Elvandvarmer

Share of DHW in separate el. water heaters	0,0
Heat loss from hot-water tank	0,0 W/K
Temp. factor for setup room	1,00
Gas water heater	
Description	Gasvandvarmer
Share of DHW in separate gas water heaters	0,0
Heat loss from hot-water tank	0,0 W/K
Efficiency	0,5
Pilot flame	50,0 W
Temp. factor for setup room	1,00

District heat exchanger	
Description	Ny fjernvarmeveksler
Nominal effect	80,0 kW
Heat loss	1,0 W/K
DHW heating through exchanger	No
Exchanger temperature, min	60,0 °C
Temp. factor for setup room	0,00
Automatics, stand-by	5,0 W

Other room heating	
Direct el for room heating	
Description	Supplerende direkte rumopvarmning
Share of floor area	0,0
Wood stoves, gas radiators etc.	
Description	
Share of floor area	0,0
Efficiency	0,4
Air flow requirement	0,1 m³/s

Solar heating plant	
Description	Nyt solvarmeanlæg
Type	Domestic hot water

Solar collector		
Area 0,0 m²	Start 0,8	-
Coefficient of heat loss a1 3,5 W/m²K	Coefficient of heat loss a2 0,0 W/m²K	Anglefactor 0,9
Orientation S	Slope 0,0 °	-
Horizon 10,0 °	Left 0,0 °	Right 0,0 °
Solar collector pipe		
Length 0,0 m	Heat loss 0,00 W/mK	Circuit 0,8
Electricity		
Pump in solar collector circuit 50,0 W	Automatics, stand-by 5,0 W	

Solar cells		
Description	Nyt solcelle anlæg	
Solar cells		
Area 25,0 m²	Orientation v	Slope 8,0 °
Horizon 10,0 °	Left 10,0 °	Right 10,0 °
Additional		
Peak power 0,140 kW/m²	Efficiency 0,80	

Model: Tranehavevej_Be10_41,5kWh	**SBi Beregningskerne 5, 11, 7, 21**

Be10 results: Tranehavevej Børneinstitution

Energy requirement

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heating	5,74	4,86	3,73	1,48	0,70	0,63	0,66	0,66	0,67	1,67	3,42	5,03	29,24
El. for service of buildings	1,04	0,72	0,56	0,34	0,26	0,28	0,33	0,40	0,49	0,77	0,95	1,10	7,23
Excess temperature in rooms	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Total energy requirement

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
BR 2010	8,34	6,65	5,13	2,32	1,34	1,34	1,49	1,65	1,90	3,59	5,80	7,78	47,33
kWh/m²	8,5	6,8	5,3	2,4	1,4	1,4	1,5	1,7	1,9	3,7	5,9	8,0	48,4
Low energy 2015	7,19	5,68	4,38	2,03	1,20	1,21	1,36	1,52	1,77	3,26	5,11	6,78	41,48
kWh/m²	7,4	5,8	4,5	2,1	1,2	1,2	1,4	1,6	1,8	3,3	5,2	6,9	42,5
Buildings 2020	5,31	4,21	3,25	1,50	0,88	0,89	1,00	1,11	1,29	2,39	3,76	5,00	30,57
kWh/m²	5,4	4,3	3,3	1,5	0,9	0,9	1,0	1,1	1,3	2,4	3,9	5,1	31,3

Heat requirement. External supply to building

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Boiler/district heating	5,74	4,86	3,73	1,48	0,70	0,63	0,66	0,66	0,67	1,67	3,42	5,03	29,24
Gas radiators	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Gas water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Cooling	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	5,74	4,86	3,73	1,48	0,70	0,63	0,66	0,66	0,67	1,67	3,42	5,03	29,24
kWh/m²	5,9	5,0	3,8	1,5	0,7	0,6	0,7	0,7	0,7	1,7	3,5	5,1	29,9

El. requirement. External supply to building. Building service

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Central heating plant	65	59	65	46	0	0	0	0	0	61	63	65	426
Domestic hot water	7	7	7	7	7	7	7	7	7	7	7	7	88
Ventilation plant	286	258	286	343	458	501	533	518	403	328	277	286	4477
Boiler/district heating	4	3	4	4	4	4	4	4	4	4	4	4	44
Heat pump	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar heat	0	0	0	0	0	0	0	0	0	0	0	0	0
Room heating	0	0	0	0	0	0	0	0	0	0	0	0	0
Local el. water heaters	0	0	0	0	0	0	0	0	0	0	0	0	0
Cooling	0	0	0	0	0	0	0	0	0	0	0	0	0
Lighting	715	480	379	252	230	217	226	241	306	493	656	768	4963
Total for building service	1077	807	742	652	699	729	770	771	720	893	1007	1130	9997
kWh/m²	1,1	0,8	0,8	0,7	0,7	0,7	0,8	0,8	0,7	0,9	1,0	1,2	10,2

El. requirement. External supply to building. Other el. consumption

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Other lighting	0	0	0	0	0	0	0	0	0	0	0	0	0
Equipment	1298	1172	1298	1256	1298	1256	1298	1298	1256	1298	1256	1298	15283
Total for other	1298	1172	1298	1256	1298	1256	1298	1298	1256	1298	1256	1298	15283
kWh/m²	1,3	1,2	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	15,6

El. requirement. External supply to building. Total el. requirement

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
The building	2375	1980	2040	1909	1997	1985	2068	2069	1976	2191	2263	2428	25280
Solar cell performance	40	90	183	315	443	448	436	373	228	124	54	27	2762
Wind mill performance	0	0	0	0	0	0	0	0	0	0	0	0	0
Resulting el. requirement	1037	717	559	338	256	281	335	398	492	769	952	1103	7235
El. for heating	0	0	0	0	0	0	0	0	0	0	0	0	0
El. for other purpose than heating	1037	717	559	338	256	281	335	398	492	769	952	1103	7235
Room heating, Heating requirement													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
In rooms	4,76	3,96	2,84	0,77	0,00	0,00	0,00	0,00	0,00	0,99	2,68	4,12	20,13
Heat coil	0,33	0,31	0,24	0,07	0,01	0,00	0,00	0,00	0,01	0,02	0,10	0,25	1,33
Pipe loss	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	5,09	4,27	3,08	0,84	0,01	0,00	0,00	0,00	0,01	1,01	2,78	4,37	21,46
Total, kWh/m²	5,2	4,4	3,2	0,9	0,0	0,0	0,0	0,0	0,0	1,0	2,8	4,5	22,0
Room heating, Fulfilment of heat requirement													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Boiler/district heating	5,09	4,27	3,08	0,84	0,01	0,00	0,00	0,00	0,01	1,01	2,78	4,37	21,46
Solar heating plant	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heat pump	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El. heating of rooms	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El-VF in ventilation plant	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wood stoves etc.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	5,09	4,27	3,08	0,84	0,01	0,00	0,00	0,00	0,01	1,01	2,78	4,37	21,46
Domestic hot water, Hot-water requirement													
m³	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Total consumption	8,3	7,5	8,3	8,0	8,3	8,0	8,3	8,3	8,0	8,3	8,0	8,3	97,7
Domestic hot water, Supply													
m³	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Central heating plant	8,3	7,5	8,3	8,0	8,3	8,0	8,3	8,3	8,0	8,3	8,0	8,3	97,7
Local el. heaters	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Local gas heaters	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Total	8,3	7,5	8,3	8,0	8,3	8,0	8,3	8,3	8,0	8,3	8,0	8,3	97,7
Domestic hot water, Heating requirement													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Central water container	0,44	0,39	0,44	0,42	0,44	0,42	0,44	0,44	0,42	0,44	0,42	0,44	5,13
Local el. heater	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Local gas heater	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heating total	0,44	0,39	0,44	0,42	0,44	0,42	0,44	0,44	0,42	0,44	0,42	0,44	5,13
Loss central water container	0,05	0,04	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,55
Loss connection pipes for DHW	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,37
Domestic hot water, pipe loss	0,14	0,13	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	1,67
Loss local el. water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Loss local. gas water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total loss	0,22	0,20	0,22	0,21	0,22	0,21	0,22	0,22	0,21	0,22	0,21	0,22	2,59

Total	0,66	0,59	0,66	0,63	0,66	0,63	0,66	0,66	0,63	0,66	0,63	0,66	7,72
kWh/m²	0,7	0,6	0,7	0,6	0,7	0,6	0,7	0,7	0,6	0,7	0,6	0,7	7,9
Domestic hot water, Fulfilment of heating requirement													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Boiler/district heating	0,66	0,59	0,66	0,63	0,66	0,63	0,66	0,66	0,63	0,66	0,63	0,66	7,72
Solar heating plant	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heat pump	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El. heating of central water container	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El. tracing of DHW pipes	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Local el. water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Local gas heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	0,66	0,59	0,66	0,63	0,66	0,63	0,66	0,66	0,63	0,66	0,63	0,66	7,72
El. requirement in heating plant													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Direct room heating	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumps	65	59	65	46	0	0	0	0	0	61	63	65	426
Total	65	59	65	46	0	0	0	0	0	61	63	65	426
kWh/m²	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,1	0,4
El. requirement in hot-water discharge plant													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
El. heating of central water container	0	0	0	0	0	0	0	0	0	0	0	0	0
El. tracing of DHW pipes	0	0	0	0	0	0	0	0	0	0	0	0	0
Charging pump	0	0	0	0	0	0	0	0	0	0	0	0	0
Circulating pump	7	7	7	7	7	7	7	7	7	7	7	7	88
Total	7	7	7	7	7	7	7	7	7	7	7	7	88
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement in ventilation plant													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heat coils	0	0	0	0	0	0	0	0	0	0	0	0	0
Ventilators	286	258	286	343	458	501	533	518	403	328	277	286	4477
Total	286	258	286	343	458	501	533	518	403	328	277	286	4477
kWh/m²	0,3	0,3	0,3	0,4	0,5	0,5	0,5	0,5	0,4	0,3	0,3	0,3	4,6
Boiler/district heating exchanger, Heat													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Performance	5,74	4,86	3,73	1,48	0,67	0,63	0,66	0,66	0,64	1,67	3,42	5,03	29,18
Consumption	5,78	4,89	3,77	1,51	0,70	0,63	0,66	0,66	0,67	1,70	3,45	5,06	29,46
Utilizable heat loss	0,03	0,03	0,03	0,03	0,00	0,00	0,00	0,00	0,00	0,03	0,03	0,03	0,22
Efficiency	99	99	99	98	95	100	100	100	95	98	99	99	99
Boiler/district heating exchanger, El. requirement													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Burner, kWh	0	0	0	0	0	0	0	0	0	0	0	0	0
Automatics, kWh	4	3	4	4	4	4	4	4	4	4	4	4	44
Total	4	3	4	4	4	4	4	4	4	4	4	4	44

kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Heat pump, Heat													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Performance, Room heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Performance, DHW	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Contribution ratio, room heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Contribution ratio, DHW	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Heat pump, El. requirement													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
El. requirement, room heating	0	0	0	0	0	0	0	0	0	0	0	0	0
El. requirement, stand-by room heating	0	0	0	0	0	0	0	0	0	0	0	0	0
El. requirement, DHW	0	0	0	0	0	0	0	0	0	0	0	0	0
El. requirement, stand-by DHW	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Solar heating plant, Heat													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Performance, Room heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Performance, DHW	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Contribution ratio, room heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Contribution ratio, DHW	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Solar heating plant, El. requirement													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Pump	0	0	0	0	0	0	0	0	0	0	0	0	0
Automatics	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement for lighting. Included in the building's performance													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
General during service life	715	480	379	252	230	217	226	241	306	493	656	768	4963
General stand-by when not in service	0	0	0	0	0	0	0	0	0	0	0	0	0
Working lights in service life	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	715	480	379	252	230	217	226	241	306	493	656	768	4963
kWh/m²	0,7	0,5	0,4	0,3	0,2	0,2	0,2	0,2	0,3	0,5	0,7	0,8	5,1
El. requirement for lighting. Other lighting													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
During service	0	0	0	0	0	0	0	0	0	0	0	0	0
Night consumption	0	0	0	0	0	0	0	0	0	0	0	0	0
Basement car parkings	0	0	0	0	0	0	0	0	0	0	0	0	0
Outdoor lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0

kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

El. requirement for epuipment

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Equipment	1298	1172	1298	1256	1298	1256	1298	1298	1256	1298	1256	1298	15283
Night consumption, equipment	0	0	0	0	0	0	0	0	0	0	0	0	0
Special equipment during service	0	0	0	0	0	0	0	0	0	0	0	0	0
Special equipment always	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1298	1172	1298	1256	1298	1256	1298	1298	1256	1298	1256	1298	15283
kWh/m²	1,3	1,2	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	15,6

Solar cells and wind mills

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Total el. requirement	2375	1980	2040	1909	1997	1985	2068	2069	1976	2191	2263	2428	25280
Solar cells	40	90	183	315	443	448	436	373	228	124	54	27	2762
Wind mills	0	0	0	0	0	0	0	0	0	0	0	0	0
Total performance	40	90	183	315	443	448	436	373	228	124	54	27	2762
Balance	-2335	-1889	-1857	-1594	-1554	-1537	-1633	-1696	-1748	-2067	-2208	-2401	-22518
Surplus	0	0	0	0	0	0	0	0	0	0	0	0	0
Adjustment of performance	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar cells, included	40	90	183	315	443	448	436	373	228	124	54	27	2762
kWh/m²	0,0	0,1	0,2	0,3	0,5	0,5	0,4	0,4	0,2	0,1	0,1	0,0	2,8
Wind mills, included	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Net heating requirement in rooms

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heat loss	8,34	7,64	7,50	5,82	3,85	2,36	1,90	1,98	3,28	4,68	6,12	7,58	61,06
Incident solar radiation	0,58	1,20	2,37	3,70	4,84	4,95	4,84	4,32	2,88	1,61	0,72	0,42	32,43
Internal supplement	2,88	2,43	2,54	2,35	2,39	2,31	2,39	2,40	2,40	2,66	2,75	2,93	30,43
From pipes and water container	0,22	0,20	0,22	0,21	0,22	0,21	0,22	0,22	0,21	0,22	0,21	0,22	2,59
Total supplement	3,68	3,83	5,13	6,25	7,46	7,47	7,45	6,95	5,49	4,49	3,68	3,57	65,45
Relative supplement	0,44	0,50	0,68	1,07	1,94	3,17	3,91	3,51	1,67	0,96	0,60	0,47	
Utilization factor	0,97	0,96	0,91	0,76	0,49	0,31	0,25	0,28	0,56	0,81	0,93	0,97	0,68
Part of month with heating	1,00	1,00	1,00	0,72	0,00	0,00	0,00	0,00	0,00	0,93	1,00	1,00	
Heating requirement	4,76	3,96	2,84	0,77	0,00	0,00	0,00	0,00	0,00	0,99	2,68	4,12	20,13
Heating in ventilating heat surface	0,33	0,31	0,24	0,07	0,01	0,00	0,00	0,00	0,01	0,02	0,10	0,25	1,33
Net. room heating	5,09	4,27	3,08	0,84	0,01	0,00	0,00	0,00	0,01	1,01	2,78	4,37	21,46
Total, kWh/m²	5,2	4,4	3,2	0,9	0,0	0,0	0,0	0,0	0,0	1,0	2,8	4,5	20,6

Solar shield, forced vent., night vent. and cooling

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Solar shield, red. factor	0,82	0,80	0,80	0,80	0,80	0,83	0,82	0,82	0,80	0,80	0,83	0,85	
Forcing, share	0,00	0,00	0,00	0,25	0,57	0,76	0,81	0,76	0,43	0,15	0,00	0,00	
Night ventilation, share	0,00	0,00	0,00	0,00	0,24	0,33	0,35	0,32	0,18	0,00	0,00	0,00	
Mechanical cooling, share	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	

Mean ventilation. Sum of natural and mechanical ventilation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
m^3/s	0,37	0,37	0,37	0,40	0,46	0,49	0,50	0,49	0,43	0,39	0,37	0,37	
l/s m^2	0,37	0,37	0,37	0,41	0,47	0,50	0,51	0,50	0,44	0,40	0,37	0,37	

Share of time at 26,0 °C room temperature or above

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Time sha<re	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Mechanical cooling, net

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
MWh	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
kWh/m^2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Total heat loss, W/m^2

Heat loss	12,8
Ventilation without HRV in winter	43,2
Total	56,1
Ventilation with HRV in winter	10,1
Total	22,9

Be10 model: Traneh._Be10_tailered incl. cooling Date 20.02.2013 11.42

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The building	
Building type	Other
Rotation	320,0 deg
Area of heated floor	977,0 m²
Area existing / other usage	0,0 m²
Heat capacity	120,0 Wh/K m²
Normal usage time	50 hours/week
Usage time, start at - end at, time	7 - 17

Calculation rules	
Calculation rules	BR: Actual conditions
Suplement to energy frame	1,3 kWh/m² år

Heat supply and cooling	
Basic heat supply	District heating
Electric panels	No
Wood stoves, gas radiators etc.	No
Solar heating plant	No
Heat pumps	No
Solar cells	Yes
Wind mills	No
Mechanical cooling	Yes

Room temperatures, set points	
Heating	22,0 °C
Wanted	23,0 °C
Natural ventilation	24,0 °C
Mechanical cooling	25,0 °C
Heating store	15,0 °C

Dimensioning temperatures	
Room temp.	22,0 °C
Outdoor temp.	-12,0 °C
Room temp. store	15,0 °C

External walls, roofs and floors

Building component	Area (m^2)	U (W/m^2K)	b	Dim.Inside (C)	Dim.Outside (C)
Facade Nord	9,4	0,10	1,000		
Facade Syd	63,8	0,10	1,000		
Facade Vest	38,1	0,10	1,000		
Facade Øst	116,1	0,10	1,000		
Terrændæk	977,0	0,10	1,000	30	10
Tag	945,5	0,10	1,000		
Vægge i nord mod uopvarmet liggehal (fra CAD)	55,1	0,10	0,700		
Opgybning ovenlys	57,5	0,14	1,000		
Ialt	2262,5	-	-	-	-

Foundations etc.

Building component	l (m)	Loss (W/mK)	b	Dim.Inside (C)	Dim.Outside (C)
Vinduer og døre (opgørelse - dobbelt ved tilstødende vinduer)	258,8	0,01	1,000		
Ovenlys konstruktion øst + vest	108,5	0,10	1,000		
Fundament	156,3	0,10	1,300	30	
Ialt	523,6	-	-	-	-

Windows and outer doors

Building component	Number	Orient	Inclination	Area (m^2)	U (W/m^2K)	b	Ff (-)	g (-)	Shading	Fc (-)	Dim.Inside (C)	Dim.Outside (C)
Vinduer i nord facade	1	n	90,0	5,4	0,90	1,000	0,80	0,57	Default	0,20		
Vinduer i øst facade	1	ø	90,0	23,9	0,90	1,000	0,80	0,57	Default	0,20		
Vinduer i syd facade	1	s	90,0	7,8	0,90	1,000	0,80	0,57	Default	0,20		
Ovenlys øst	1	nø	12,0	25,7	1,20	1,000	0,80	0,43	Default	1,00		
Ovenlys vest	1	sv	12,0	17,1	1,20	1,000	0,80	0,43	Default	1,00		
vinduer fælles espalier højre	2	v	90,0	3,9	0,90	1,000	0,80	0,57	GR udhæng m. højre ved fælles espalier	0,20		
Vinduer m. udhæng, fællesrum	2	v	90,0	3,9	0,90	1,000	0,80	0,57	Fællesrum, vest udhæng	0,20		
vindue, vindfanf	1	s	90,0	1,9	0,90	1,000	0,80	0,57	Skygge fra bygning,	0,20		

									syd højre			
Vinduer m. udhæng mod syd & nord	2	v	90,0	3,9	0,90	1,000	0,80	0,57	GR længst mod syd/nord, vest udhæng top + højre, venstre	0,20		
Vinduer fælles espalier venstre	2	v	90,0	3,9	0,90	1,000	0,80	0,57	GR udhæng m. venstre ved fælles espalier	0,20		
Døre i vest ved espalier	7	v	90,0	2,3	0,90	1,000	0,80	0,57	Skygge døre ved espalier vest	0,80		
Resten af dørene	4	v	90,0	1,9	0,90	1,000	0,80	0,57	Default	0,80		
Vinduer ved køkken	3	v	90,0	2,5	0,90	1,000	0,80	0,57	Default	0,20		
GR Vinduer ved siden af udhæng venstre	2	v	90,0	4,4	0,90	1,000	0,80	0,57	GR ved siden af udhæng venstre	0,20		
GR Vinduer ved siden af udhæng højre	2	v	90,0	4,4	0,90	1,000	0,80	0,57	GR ved siden af udhæng højre	0,20		
GR Vinduer ved siden af værksted	1	v	90,0	4,4	0,90	1,000	0,80	0,57	GR ved siden af værksted	0,20		
GR Vinduer ved siden af WC	1	v	90,0	4,4	0,90	1,000	0,80	0,57	GR ved siden af ude WC	0,20		
Ialt	34	-	-	170,7	-	-	-	-	-	-	-	-

Shading					
Description	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening (%)
Default	15	0	0	0	10
Fællesrum, vest udhæng	15	70	38	42	10
Skygge fra bygning, syd venstre	15	0	80	0	10
Skygge fra bygning, syd højre	15	0	0	80	10
GR længst mod syd/nord, vest udhæng top + højre, venstre	15	40	47	47	10

GR udhæng m. venstre ved fælles espalier	15	40	47	0	10
GR udhæng m. højre ved fælles espalier	15	40	0	47	10
GR ved siden af udhæng venstre	15	0	30	0	10
GR ved siden af udhæng højre	15	0	0	30	10
GR ved siden af værksted	15	0	66	30	10
GR ved siden af ude WC	15	0	47	75	10
Skygge fra bygning, nord venstre	15	0	80	0	10
Skygge fra bygning, nord højre	15	0	0	80	10
Skygge døre ved espalier vest	15	40	47	47	10

Ventilation

Zone	Area (m²)	Fo, -	qm (l/s m²), Winter	n vgv (-)	ti (°C)	El-HC	qn (l/s m²), Winter	qi,n (l/s m²), Winter	SEL (kJ/m³)	qm,s (l/s m²), Summer	qn,s (l/s m²), Summer	qm,n (l/s m²), Night	qn,n (l/s m²), Night
Grupperum børneh./vuggest.	264,0	1,00	2,20	0,85	18,0	No	0,10	0,06	1,3	1,80	1,80	0,10	0,06
Kontor/personalerum/samtalerum	65,3	1,00	0,60	0,85	18,0	No	0,10	0,06	1,3	1,00	1,50	0,10	0,06
Køkken, pæd	22,0	1,00	1,00	0,85	18,0	No	0,10	0,06	1,3	2,00	0,80	0,10	0,06
Toilet/puslerum	103,0	1,00	0,80	0,85	18,0	No	0,10	0,06	1,3	2,00	0,70	0,10	0,06
Garderobe/tørrerum/vindfang	298,0	1,00	0,80	0,85	18,0	No	0,10	0,06	1,3	2,00	1,20	0,10	0,06
Andet	174,7	1,00	0,80	0,85	18,0	No	0,10	0,06	1,3	2,00	0,70	0,10	0,06
Køkken, prod	50,0	1,00	1,00	0,65	18,0	No	0,10	0,06	1,3	2,00	1,60	0,10	0,06

Internal heat supply

Zone	Area (m²)	Persons (W/m²)	App. (W/m²)	App,night (W/m²)
Køkken (areal ifølge tegnigner)	50	7,0	10,0	0,0
Resten af huset	927	7,0	6,0	0,0

Lighting

Zone	Area (m²)	General (W/m²)	General (W/m²)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m²)	Other (W/m²)	Stand-by (W/m²)	Night (W/m²)
Køkken (areal ifølge tegninger)	77,4	0,5	5,0	300	2,00	K	0,80	0,0	0,0	0,0	0,0
Grupperum børnehave/vuggestue	283,2	0,5	5,0	200	2,00	K	0,90	0,0	0,0	0,0	0,0
toilet/puslerum	102,5	0,5	5,0	200	2,00	K	0,80	0,0	0,0	0,0	0,0
Vindfang/grovgarderobe/tørrerum	298,1	0,5	5,0	200	1,00	K	0,80	0,0	0,0	0,0	0,0

Personalerum/samtale/arbejdsrum	65,3	0,5	5,0	500	2,00	K	0,80	0,0	0,0	0,0	0,0
Andet	150,5	0,5	5,0	200	1,00	U	0,70	0,0	0,0	0,0	0,0

Other el. consumption	
Outdoor lighting	0,0 W
Spec. apparatus, during service	0,0 W
Spec. apparatus, always	0,0 W

Basement car parkings etc.											
Zone	Area (m²)	General (W/m²)	General (W/m²)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m²)	Other (W/m²)	Stand-by (W/m²)	Night (W/m²)

Mechanical cooling	
Description	Mekanisk køling
Share of floor area	0,27
El-demand	0,25 kWh-el/kWh-cool
Heat-demand	0,00 kWh-heat/kWh-cool
Load factor	1
Heat capacity phase shift (cooling)	0 Wh/m²
Increase factor	1,50
Documentation	

Heat distribution plant		
Composition and temperature		
Supply pipe temperature	70,0 °C	
Return pipe temperature	40,0 °C	
Type of plant	2-string	Anlægstype

Pumps				
Pump type	Description	Number	Pnom	Fp
Constant service all year		0	0,0 W	0,00
Constant service during heating season	Opvarmningspumpe	1	100,0 W	0,40
Constant service during heating season	Bl. sløjfe	3	40,0 W	0,40

Heating pipes					
Pipe lengths in supply and return	l (m)	Loss (W/mK)	b	Outdoor comp (J/N)	Unused summer (J/N)
Rørfordeling til gulvvarme	0,0	0,00	1,000	N	N

Domestic hot water	
Description	Varmt brugsvand
Hot-water consumption, average for the building	100,0 litre/year per m² of floor area
Domestic hot water temp.	55,0 °C

Hot-water tank	
Description	Ny varmtvandsbeholder
Number of hot-water containers	1,0
Tank volume	800,0 liter
Supply temperature from central heating	70,0 °C
El. heating of DHW	No
Solar heat tank with heating coil	No
Heat loss from hot-water tank	1,8 W/K
Temp. factor for setup room	0,0

Charging pump	
Effect	0,0 W
Controled	No
Charge effect	0,0 kW

Heat loss from connector pipe to DHW tank			
Length	Loss	b	Description
6,0 m	0,2 W/K	0,00	

Cirkulating pump for DHW	
Description	PumpCirc
Number	1,0
Effect	25,0 W
Number	0,0
Effect	0,0 W
Reduction factor	0,40 W
El. tracing of discharge water pipe	No

Domestic hot water discharge pipes			
Pipe lengths in supply and return	l (m)	Loss (W/mK)	b
	80,0	0,17	0,000

Water heaters

Electric water heater

Description	Elvandvarmer
Share of DHW in separate el. water heaters	0,0
Heat loss from hot-water tank	0,0 W/K
Temp. factor for setup room	1,00

Gas water heater

Description	Gasvandvarmer
Share of DHW in separate gas water heaters	0,0
Heat loss from hot-water tank	0,0 W/K
Efficiency	0,5
Pilot flame	50,0 W
Temp. factor for setup room	1,00

District heat exchanger

Description	Ny fjernvarmeveksler
Nominal effect	80,0 kW
Heat loss	1,0 W/K
DHW heating through exchanger	No
Exchanger temperature, min	60,0 °C
Temp. factor for setup room	0,00
Automatics, stand-by	5,0 W

Other room heating

Direct el for room heating

Description	Supplerende direkte rumopvarmning
Share of floor area	0,0

Wood stoves, gas radiators etc.

Description	
Share of floor area	0,0
Efficiency	0,4
Air flow requirement	0,1 m³/s

Solar heating plant

Description	Nyt solvarmeanlæg	
Type	Domestic hot water	
Solar collector		
Area 0,0 m²	Start 0,8	-
Coefficient of heat loss a1 3,5 W/m²K	Coefficient of heat loss a2 0,0 W/m²K	Anglefactor 0,9
Orientation S	Slope 0,0 °	-
Horizon 10,0 °	Left 0,0 °	Right 0,0 °
Solar collector pipe		
Length 0,0 m	Heat loss 0,00 W/mK	Circuit 0,8
Electricity		
Pump in solar collector circuit 50,0 W	Automatics, stand-by 5,0 W	

Solar cells		
Description	Nyt solcelle anlæg	
Solar cells		
Area 25,0 m²	Orientation v	Slope 8,0 °
Horizon 10,0 °	Left 10,0 °	Right 10,0 °
Additional		
Peak power 0,140 kW/m²	Efficiency 0,80	

Model: Traneh._Be10_tailered incl. cooling	**SBi Beregningskerne 5, 11, 7, 21**

Be10 results: Tranehavevej Børneinstitution

Energy requirement

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heating	6,30	5,40	4,47	2,49	0,75	0,62	0,64	0,64	0,95	2,48	4,14	5,65	34,54
El. for service of buildings	1,10	0,78	0,63	0,40	0,38	0,41	0,48	0,53	0,59	0,85	1,01	1,16	8,31
Excess temperature in rooms	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Total energy requirement

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
BR 2010	9,04	7,36	6,05	3,49	1,69	1,65	1,83	1,96	2,43	4,60	6,68	8,54	55,33
kWh/m²	9,3	7,5	6,2	3,6	1,7	1,7	1,9	2,0	2,5	4,7	6,8	8,7	56,6
Low energy 2015	7,78	6,28	5,16	2,99	1,54	1,53	1,71	1,83	2,23	4,10	5,85	7,42	48,42
kWh/m²	8,0	6,4	5,3	3,1	1,6	1,6	1,7	1,9	2,3	4,2	6,0	7,6	49,6
Buildings 2020	5,75	4,65	3,82	2,21	1,13	1,11	1,24	1,33	1,63	3,01	4,31	5,47	35,69
kWh/m²	5,9	4,8	3,9	2,3	1,2	1,1	1,3	1,4	1,7	3,1	4,4	5,6	36,5

Heat requirement. External supply to building

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Boiler/district heating	6,30	5,40	4,47	2,49	0,75	0,62	0,64	0,64	0,95	2,48	4,14	5,65	34,54
Gas radiators	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Gas water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Cooling	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	6,30	5,40	4,47	2,49	0,75	0,62	0,64	0,64	0,95	2,48	4,14	5,65	34,54
kWh/m²	6,4	5,5	4,6	2,5	0,8	0,6	0,7	0,7	1,0	2,5	4,2	5,8	35,4

El. requirement. External supply to building. Building service

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Central heating plant	65	59	65	63	13	0	0	0	33	65	63	65	494
Domestic hot water	7	7	7	7	7	7	7	7	7	7	7	7	88
Ventilation plant	332	300	332	371	456	483	511	501	419	371	321	332	4727
Boiler/district heating	4	3	4	4	4	4	4	4	4	4	4	4	44
Heat pump	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar heat	0	0	0	0	0	0	0	0	0	0	0	0	0
Room heating	0	0	0	0	0	0	0	0	0	0	0	0	0
Local el. water heaters	0	0	0	0	0	0	0	0	0	0	0	0	0
Cooling	0	0	0	0	104	145	159	136	26	0	0	0	571
Lighting	730	505	405	269	238	220	231	252	328	523	673	778	5153
Total for building service	1138	874	814	714	821	860	912	900	817	971	1069	1187	11076
kWh/m²	1,2	0,9	0,8	0,7	0,8	0,9	0,9	0,9	0,8	1,0	1,1	1,2	11,3

El. requirement. External supply to building. Other el. consumption

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Other lighting	0	0	0	0	0	0	0	0	0	0	0	0	0
Equipment	1342	1212	1342	1299	1342	1299	1342	1342	1299	1342	1299	1342	15804
Total for other	1342	1212	1342	1299	1342	1299	1342	1342	1299	1342	1299	1342	15804
kWh/m²	1,4	1,2	1,4	1,3	1,4	1,3	1,4	1,4	1,3	1,4	1,3	1,4	16,2

El. requirement. External supply to building. Total el. requirement

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
The building	2480	2086	2156	2013	2163	2159	2255	2242	2116	2313	2368	2529	26881
Solar cell performance	40	90	183	315	443	448	436	373	228	124	54	27	2762
Wind mill performance	0	0	0	0	0	0	0	0	0	0	0	0	0
Resulting el. requirement	1098	784	631	399	378	411	477	527	589	847	1014	1160	8314
El. for heating	0	0	0	0	0	0	0	0	0	0	0	0	0
El. for other purpose than heating	1098	784	631	399	378	411	477	527	589	847	1014	1160	8314

Room heating, Heating requirement

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
In rooms	5,60	4,78	3,79	1,85	0,10	0,00	0,00	0,00	0,33	1,83	3,50	4,96	26,73
Heat coil	0,05	0,05	0,04	0,02	0,00	0,00	0,00	0,00	0,00	0,01	0,03	0,04	0,24
Pipe loss	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	5,65	4,82	3,83	1,87	0,10	0,00	0,00	0,00	0,33	1,84	3,52	5,00	26,97
Total, kWh/m²	5,8	4,9	3,9	1,9	0,1	0,0	0,0	0,0	0,3	1,9	3,6	5,1	27,6

Room heating, Fulfilment of heat requirement

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Boiler/district heating	5,65	4,82	3,83	1,87	0,10	0,00	0,00	0,00	0,33	1,84	3,52	5,00	26,97
Solar heating plant	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heat pump	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El. heating of rooms	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El-VF in ventilation plant	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wood stoves etc.	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	5,65	4,82	3,83	1,87	0,10	0,00	0,00	0,00	0,33	1,84	3,52	5,00	26,97

Domestic hot water, Hot-water requirement

m³	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Total consumption	8,3	7,5	8,3	8,0	8,3	8,0	8,3	8,3	8,0	8,3	8,0	8,3	97,7

Domestic hot water, Supply

m³	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Central heating plant	8,3	7,5	8,3	8,0	8,3	8,0	8,3	8,3	8,0	8,3	8,0	8,3	97,7
Local el. heaters	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Local gas heaters	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Total	8,3	7,5	8,3	8,0	8,3	8,0	8,3	8,3	8,0	8,3	8,0	8,3	97,7

Domestic hot water, Heating requirement

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Central water container	0,44	0,39	0,44	0,42	0,44	0,42	0,44	0,44	0,42	0,44	0,42	0,44	5,13
Local el. heater	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Local gas heater	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heating total	0,44	0,39	0,44	0,42	0,44	0,42	0,44	0,44	0,42	0,44	0,42	0,44	5,13
Loss central water container	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,52
Loss connection pipes for DHW	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,35
Domestic hot water, pipe loss	0,13	0,12	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	1,57
Loss local el. water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Loss local. gas water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total loss	0,21	0,19	0,21	0,20	0,21	0,20	0,21	0,21	0,20	0,21	0,20	0,21	2,44
Total	0,64	0,58	0,64	0,62	0,64	0,62	0,64	0,64	0,62	0,64	0,62	0,64	7,57
kWh/m²	0,7	0,6	0,7	0,6	0,7	0,6	0,7	0,7	0,6	0,7	0,6	0,7	7,7

Domestic hot water, Fulfilment of heating requirement

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Boiler/district heating	0,64	0,58	0,64	0,62	0,64	0,62	0,64	0,64	0,62	0,64	0,62	0,64	7,57
Solar heating plant	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heat pump	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El. heating of central water container	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
El. tracing of DHW pipes	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Local el. water heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Local gas heaters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	0,64	0,58	0,64	0,62	0,64	0,62	0,64	0,64	0,62	0,64	0,62	0,64	7,57

El. requirement in heating plant

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Direct room heating	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumps	65	59	65	63	13	0	0	0	33	65	63	65	494
Total	65	59	65	63	13	0	0	0	33	65	63	65	494
kWh/m²	0,1	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,1	0,5

El. requirement in hot-water discharge plant

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
El. heating of central water container	0	0	0	0	0	0	0	0	0	0	0	0	0
El. tracing of DHW pipes	0	0	0	0	0	0	0	0	0	0	0	0	0
Charging pump	0	0	0	0	0	0	0	0	0	0	0	0	0

Circulating pump	7	7	7	7	7	7	7	7	7	7	7	7	88
Total	7	7	7	7	7	7	7	7	7	7	7	7	88
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement in ventilation plant													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heat coils	0	0	0	0	0	0	0	0	0	0	0	0	0
Ventilators	332	300	332	371	456	483	511	501	419	371	321	332	4727
Total	332	300	332	371	456	483	511	501	419	371	321	332	4727
kWh/m²	0,3	0,3	0,3	0,4	0,5	0,5	0,5	0,5	0,4	0,4	0,3	0,3	4,8
Boiler/district heating exchanger, Heat													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Performance	6,30	5,40	4,47	2,49	0,75	0,62	0,64	0,64	0,95	2,48	4,14	5,65	34,54
Consumption	6,33	5,43	4,50	2,52	0,75	0,62	0,64	0,64	0,97	2,51	4,17	5,68	34,77
Utilizable heat loss	0,03	0,03	0,03	0,03	0,01	0,00	0,00	0,00	0,02	0,03	0,03	0,03	0,23
Efficiency	100	99	99	99	99	100	100	100	98	99	99	99	99
Boiler/district heating exchanger, El. requirement													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Burner, kWh	0	0	0	0	0	0	0	0	0	0	0	0	0
Automatics, kWh	4	3	4	4	4	4	4	4	4	4	4	4	44
Total	4	3	4	4	4	4	4	4	4	4	4	4	44
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Heat pump, Heat													
MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Performance, Room heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Performance, DHW	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Contribution ratio, room heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Contribution ratio, DHW	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Heat pump, El. requirement													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
El. requirement, room heating	0	0	0	0	0	0	0	0	0	0	0	0	0
El. requirement, stand-by room heating	0	0	0	0	0	0	0	0	0	0	0	0	0
El. requirement, DHW	0	0	0	0	0	0	0	0	0	0	0	0	0
El. requirement, stand-by DHW	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Solar heating plant, Heat													

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Performance, Room heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Performance, DHW	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Contribution ratio, room heating	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Contribution ratio, DHW	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
Solar heating plant, El. requirement													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Pump	0	0	0	0	0	0	0	0	0	0	0	0	0
Automatics	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement for lighting. Included in the building's performance													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
General during service life	730	505	405	269	238	220	231	252	328	523	673	778	5153
General stand-by when not in service	0	0	0	0	0	0	0	0	0	0	0	0	0
Working lights in service life	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	730	505	405	269	238	220	231	252	328	523	673	778	5153
kWh/m²	0,7	0,5	0,4	0,3	0,2	0,2	0,2	0,3	0,3	0,5	0,7	0,8	5,3
El. requirement for lighting. Other lighting													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
During service	0	0	0	0	0	0	0	0	0	0	0	0	0
Night consumption	0	0	0	0	0	0	0	0	0	0	0	0	0
Basement car parkings	0	0	0	0	0	0	0	0	0	0	0	0	0
Outdoor lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
El. requirement for epuipment													
kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Equipment	1342	1212	1342	1299	1342	1299	1342	1342	1299	1342	1299	1342	15804
Night consumption, equipment	0	0	0	0	0	0	0	0	0	0	0	0	0
Special equipment during service	0	0	0	0	0	0	0	0	0	0	0	0	0
Special equipment always	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1342	1212	1342	1299	1342	1299	1342	1342	1299	1342	1299	1342	15804
kWh/m²	1,4	1,2	1,4	1,3	1,4	1,3	1,4	1,4	1,3	1,4	1,3	1,4	16,2

Solar cells and wind mills

kWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Total el. requirement	2480	2086	2156	2013	2163	2159	2255	2242	2116	2313	2368	2529	26881
Solar cells	40	90	183	315	443	448	436	373	228	124	54	27	2762
Wind mills	0	0	0	0	0	0	0	0	0	0	0	0	0
Total performance	40	90	183	315	443	448	436	373	228	124	54	27	2762
Balance	-2440	-1996	-1973	-1698	-1720	-1710	-1819	-1869	-1888	-2189	-2313	-2502	-24119
Surplus	0	0	0	0	0	0	0	0	0	0	0	0	0
Adjustment of performance	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar cells, included	40	90	183	315	443	448	436	373	228	124	54	27	2762
kWh/m²	0,0	0,1	0,2	0,3	0,5	0,5	0,4	0,4	0,2	0,1	0,1	0,0	2,8
Wind mills, included	0	0	0	0	0	0	0	0	0	0	0	0	0
kWh/m²	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Net heating requirement in rooms

MWh	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heat loss	9,81	8,96	8,97	7,24	5,31	3,78	3,37	3,44	4,70	6,15	7,54	9,05	78,31
Incident solar radiation	0,53	1,07	2,12	3,30	4,30	4,40	4,31	3,85	2,58	1,45	0,65	0,38	28,95
Internal supplement	3,59	3,09	3,26	3,03	3,09	2,98	3,09	3,11	3,09	3,38	3,44	3,64	38,79
From pipes and water container	0,21	0,19	0,21	0,20	0,21	0,20	0,21	0,21	0,20	0,21	0,20	0,21	2,44
Total supplement	4,32	4,35	5,59	6,54	7,60	7,58	7,60	7,17	5,88	5,03	4,29	4,22	70,18
Relative supplement	0,44	0,48	0,62	0,90	1,43	2,01	2,26	2,08	1,25	0,82	0,57	0,47	
Utilization factor	0,97	0,96	0,93	0,83	0,63	0,48	0,43	0,46	0,69	0,86	0,94	0,97	0,76
Part of month with heating	1,00	1,00	1,00	1,00	0,20	0,00	0,00	0,00	0,52	1,00	1,00	1,00	
Heating requirement	5,60	4,78	3,79	1,85	0,10	0,00	0,00	0,00	0,33	1,83	3,50	4,96	26,73
Heating in ventilating heat surface	0,05	0,05	0,04	0,02	0,00	0,00	0,00	0,00	0,00	0,01	0,03	0,04	0,24
Net. room heating	5,65	4,82	3,83	1,87	0,10	0,00	0,00	0,00	0,33	1,84	3,52	5,00	26,97
Total, kWh/m²	5,8	4,9	3,9	1,9	0,1	0,0	0,0	0,0	0,3	1,9	3,6	5,1	27,4

Solar shield, forced vent., night vent. and cooling

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Solar shield, red. factor	0,83	0,81	0,81	0,82	0,83	0,86	0,85	0,84	0,82	0,81	0,84	0,87	
Forcing, share	0,00	0,00	0,00	0,26	0,55	0,74	0,78	0,74	0,44	0,20	0,00	0,00	
Night ventilation, share	0,00	0,00	0,00	0,00	0,25	0,35	0,38	0,35	0,20	0,00	0,00	0,00	
Mechanical cooling, share	0,00	0,00	0,00	0,00	0,17	0,24	0,27	0,24	0,13	0,00	0,00	0,00	

Mean ventilation. Sum of natural and mechanical ventilation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
m³/s	0,41	0,41	0,41	0,43	0,47	0,50	0,50	0,50	0,46	0,43	0,41	0,41	
l/s m²	0,42	0,42	0,42	0,44	0,49	0,51	0,51	0,51	0,47	0,44	0,42	0,42	

Share of time at 26,0 °C room temperature or above

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Time sha<re	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Mechanical cooling, net

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
MWh	0,00	0,00	0,00	0,00	0,28	0,39	0,42	0,36	0,07	0,00	0,00	0,00	1,52
kWh/m²	0,0	0,0	0,0	0,0	0,3	0,4	0,4	0,4	0,1	0,0	0,0	0,0	1,6

Total heat loss, W/m²

Heat loss	13,5
Ventilation without HRV in winter	52,6
Total	66,1
Ventilation with HRV in winter	11,8
Total	25,3

Appendix H - Daylight

Daylight factors are displayed as a color palette in the middle of the room at 0.75 above the floor with colors ranging from red (2%) to dark blue (0.0%). All daylight factors are simulated with CIE overcast sky conditions at 12 p.m. on the 21st of September.

The Common room

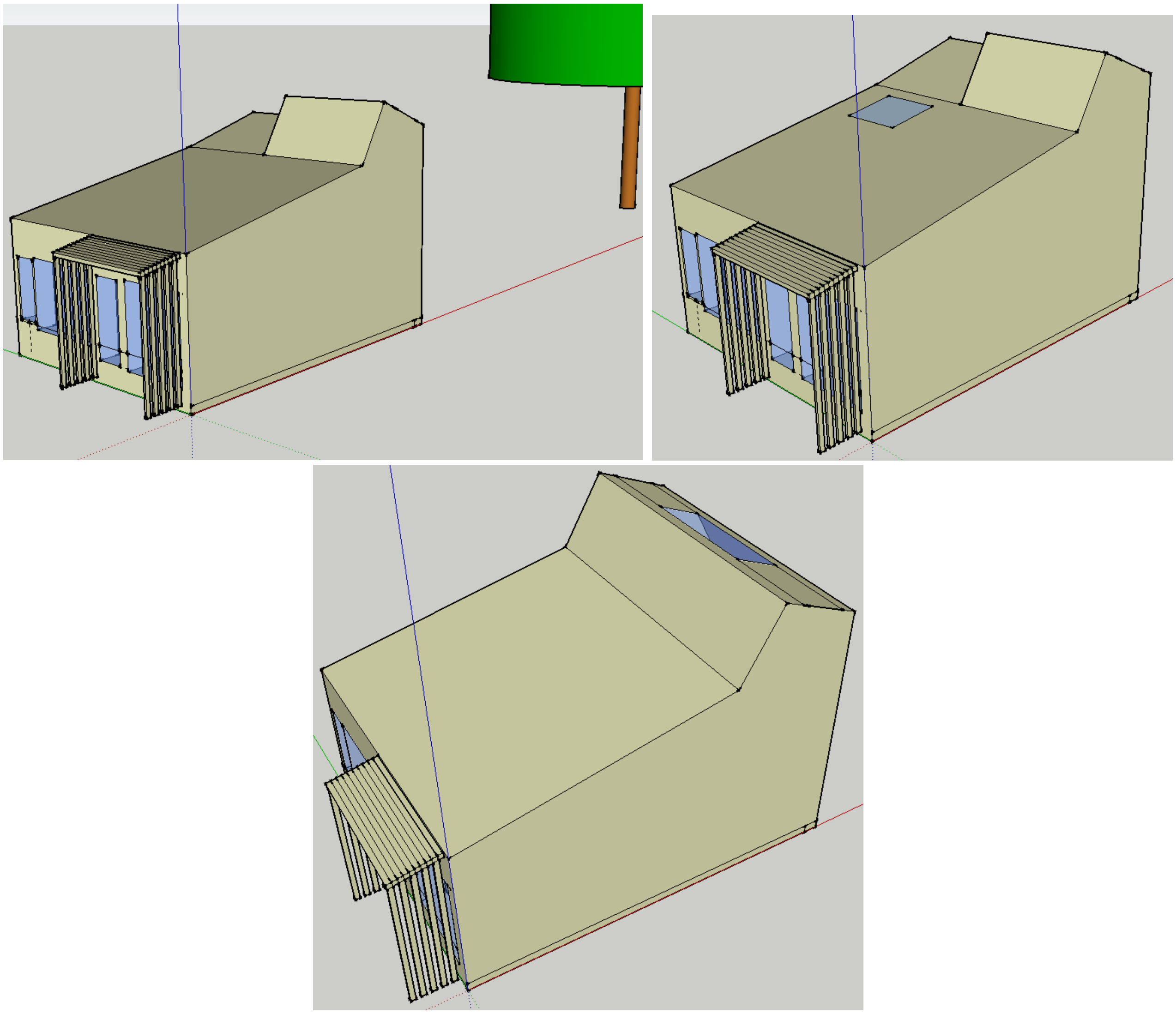


Figure 1 – Three alternative skylight designs (the construction in front of the façade is the pergola). Left corner: (# 1) original design with skylight in the side. Right corner: (#2) the original skylight location but 1 of the 3 m^2 skylight windows is moved down the roof. Bottom: (#3) the skylight construction is made as one continuous band on the roof ridge and the skylights are located in the middle of each room. The initial design was selected because it did not interfere with the exterior design. (The related daylight simulation results are displayed on the next page).

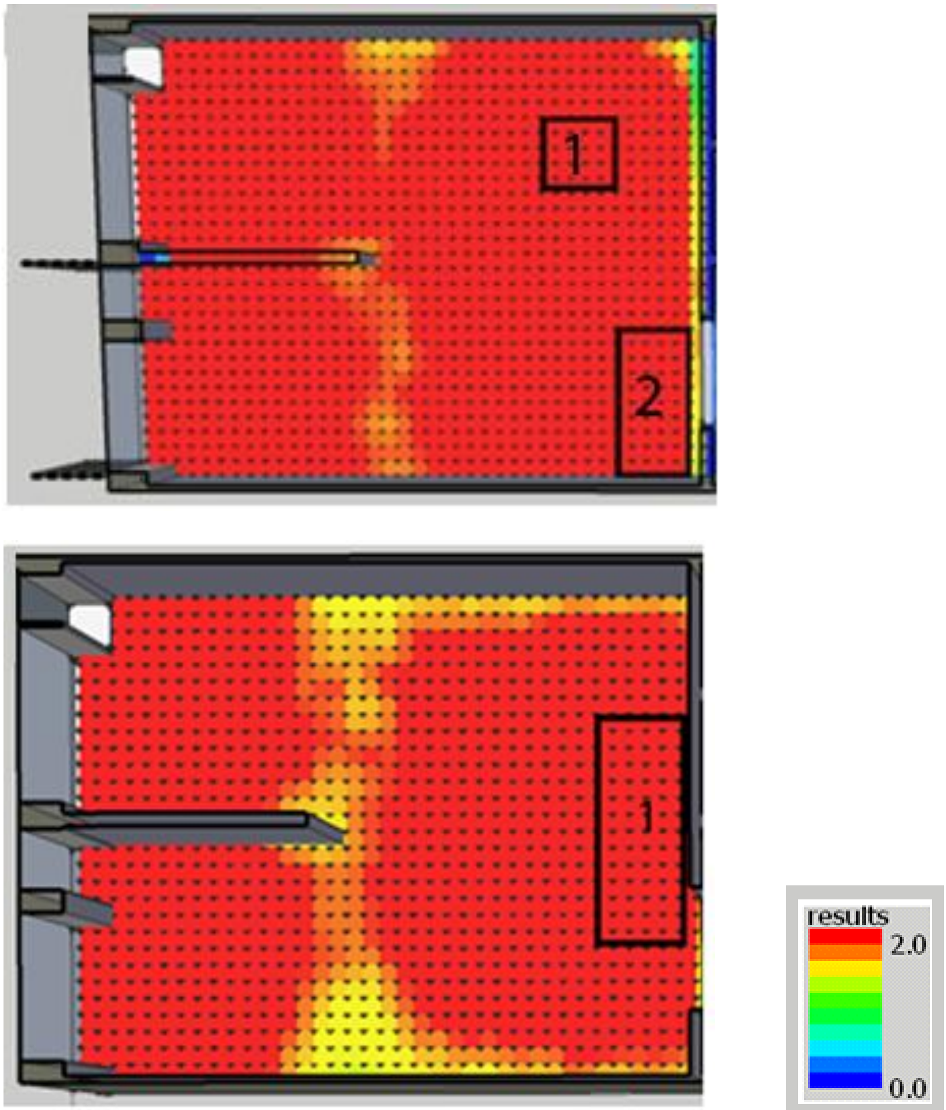


Figure 2 – Daylight factor simulation results of the scenarios of the common room illustrated in figure 1 above. (1) Left corner: The original and final design (1: the pergola outside the façade, 2) illustration of where the skylight is located). (2) Right corner: same skylight glazing area divided up into 1 m2 further down the roof and 2 m2 at the original position. (3) Again the same skylight glazing area centered in the room gives a better light distribution (the pergola has been cut in the illustration but has been included in the simulation). (Red is where there is a daylight factor of minimum 2%).

The (1) design has a relative even daylight distribution but there is one corner which is not well lit and therefore the scenario (2) and (3) has been made as alternatives. Personally the author prefers scenario (2) because of its better daylight distribution and it does not interfere too much with the skylight construction. However, the little skylight in the 2 proposal is pointed toward south west with an inclination of 12° so it would be preferable with a fixed exterior solar shading on this to eliminate direct solar radiation from this in the common room.

The kitchen

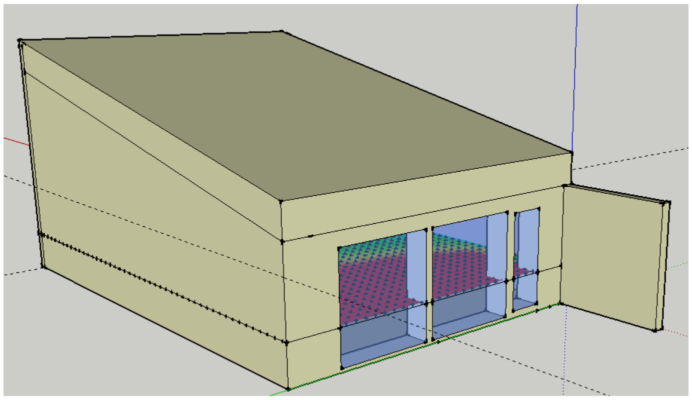


Figure 3 – View from the outside of the final design of the kitchen (see figure 5). The exterior wall to the right is pergola providing shade and the horizontal multicolored interior surface in the middle of the room is the illustration of the daylight factors.

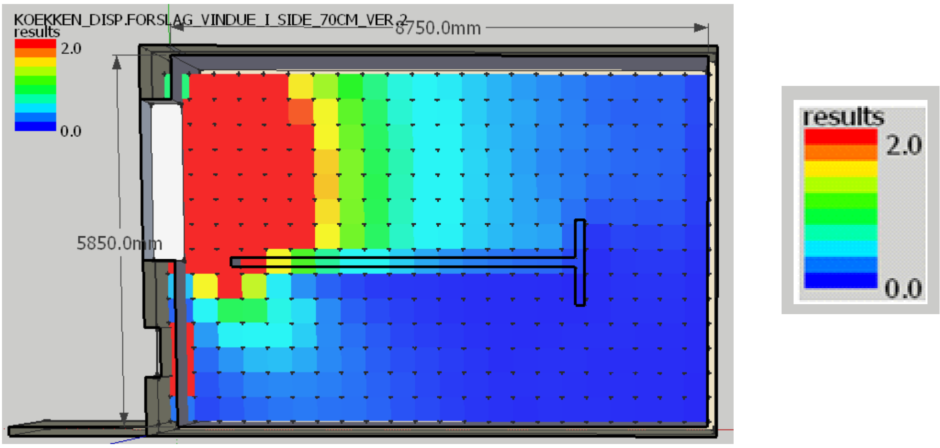


Figure 4 – Initial design of the kitchen with only one window in one side of the room and one glass door. This design did not provide very much daylight to the room. (Red is where there is a daylight factor of minimum 2%).

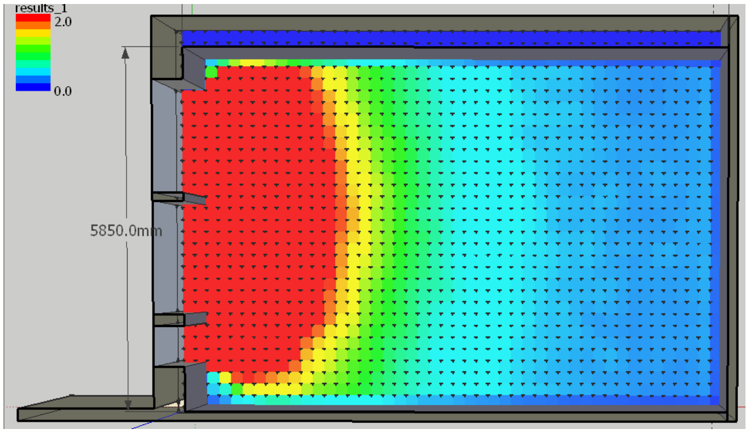


Figure 5 – Final design with daylight factors in the kitchen. The 2% border line is approx. 2 m in from the façade. A skylight at the back of the room was proposed to give a more even daylight distribution throughout the room but this was rejected on the argument that most of the work would be located near the façade. (Red is where there is a daylight factor of minimum 2%).

Office

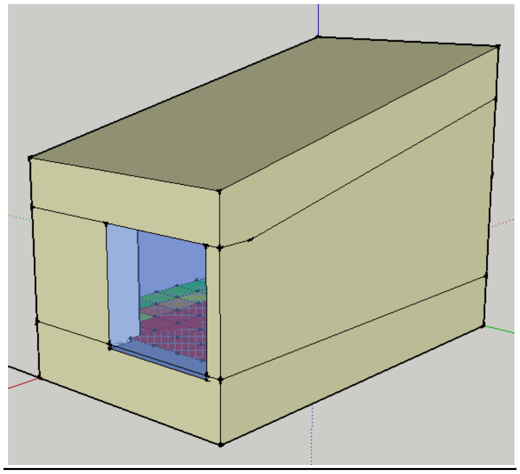


Figure 6 – The office seen from the outside. The office is orientated toward the Northeast. The simulation includes a 9 m tall tree at approx. 6 m distance from the office façade.

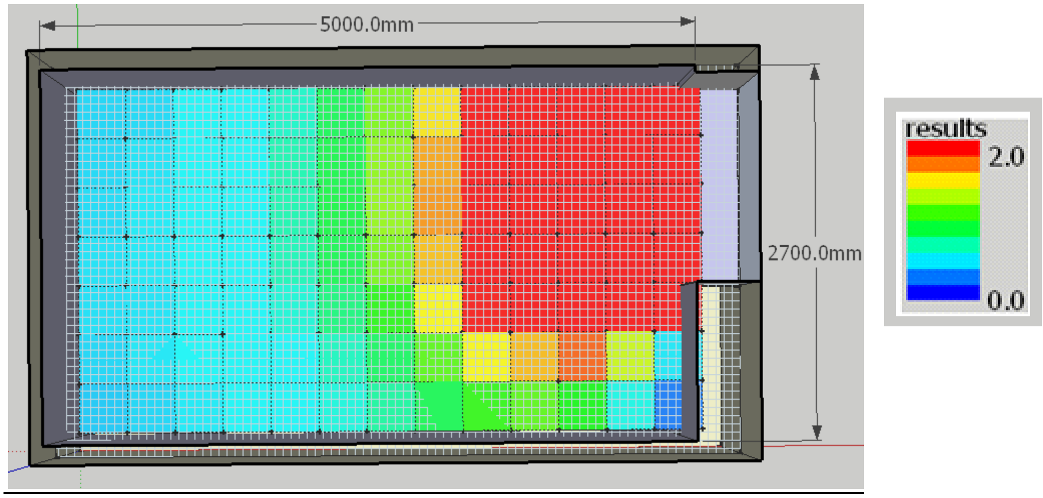


Figure 7 – The daylight factor border line of 2% is only approx. 2 m from the façade partially due to the large tree outside the window. This would have to be considered for the furniture plan to ensure that the office desk is located near the façade window. (Red is where there is a daylight factor of minimum 2%).

RadianceIES simulations

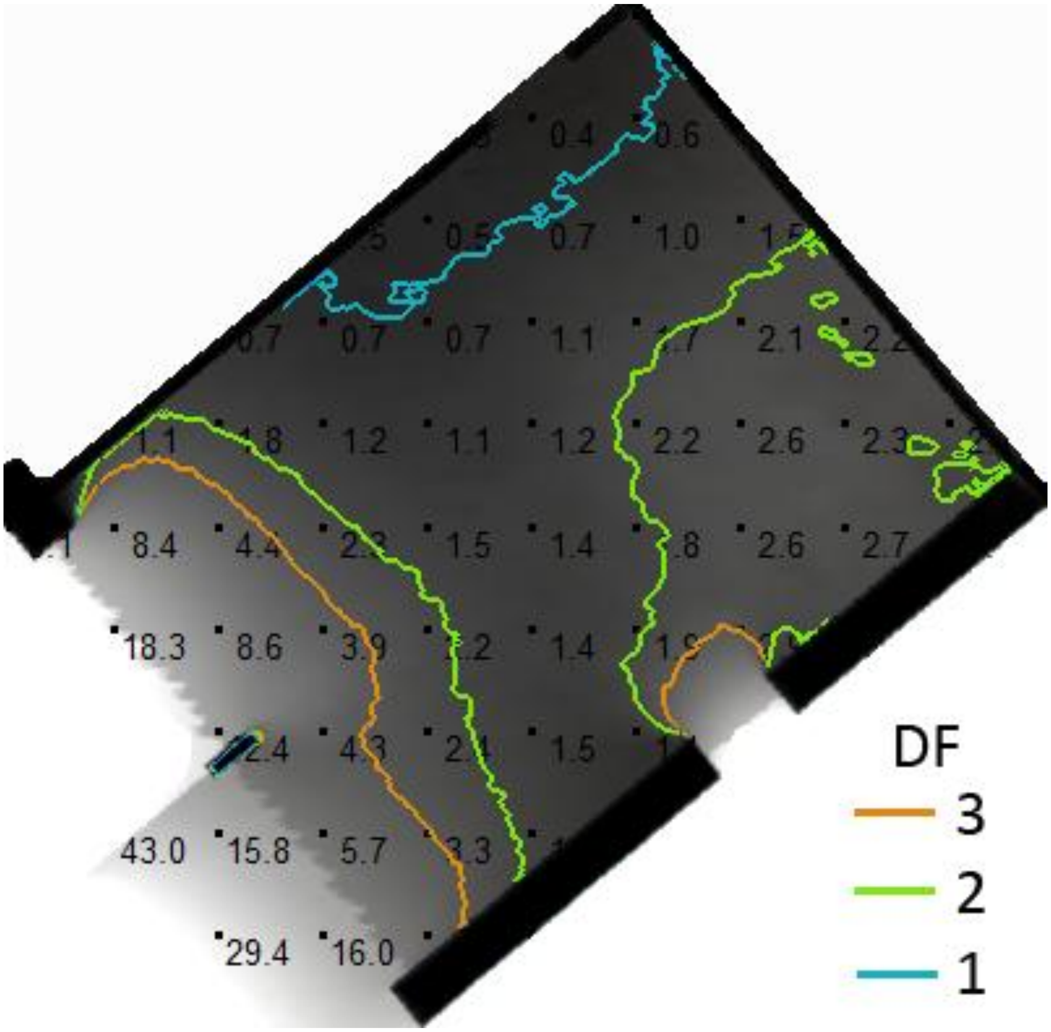


Figure 8 – Daylight factors in ommon room 1,

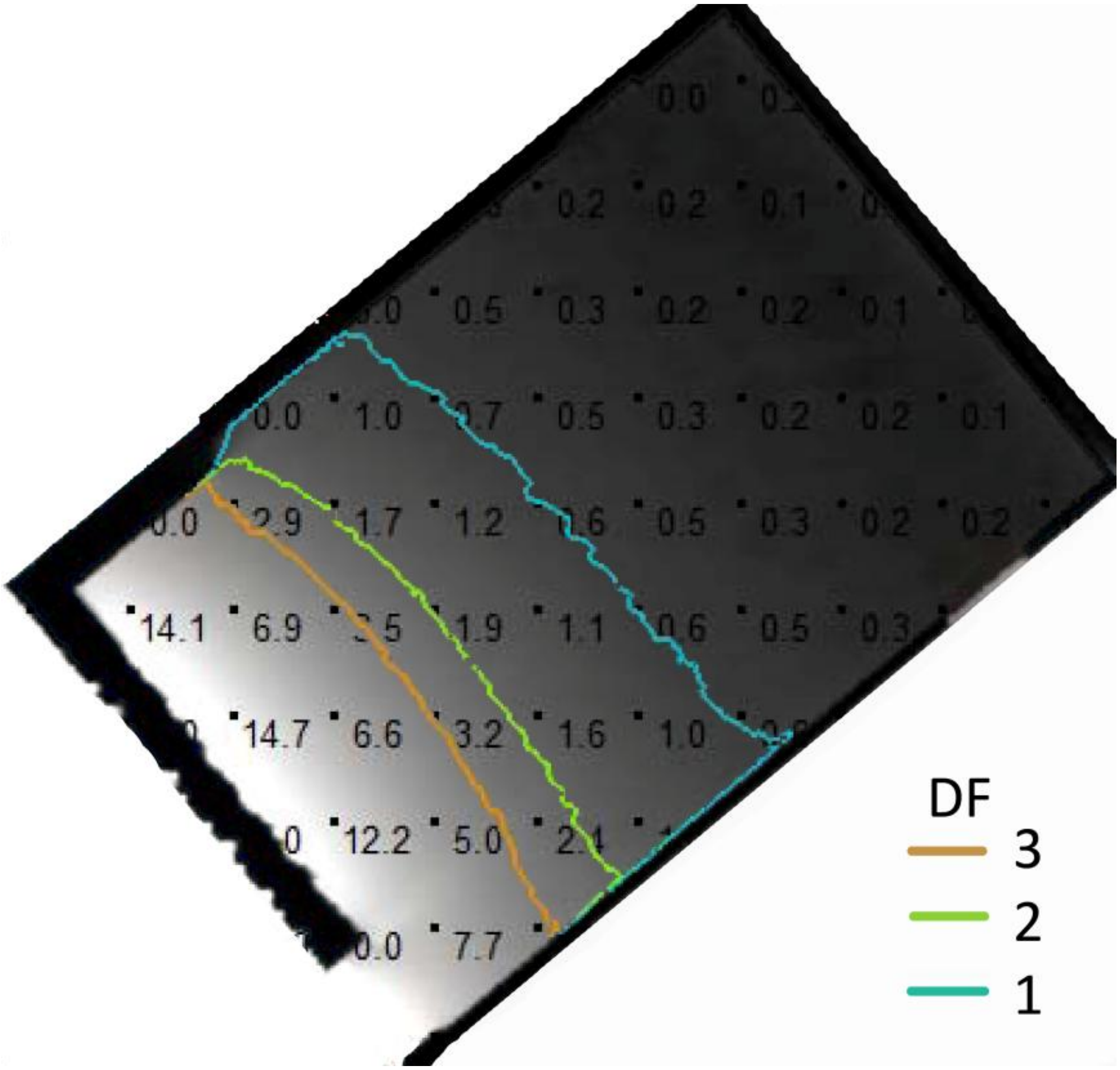


Figure 9 – Daylight factors in the kitchen.

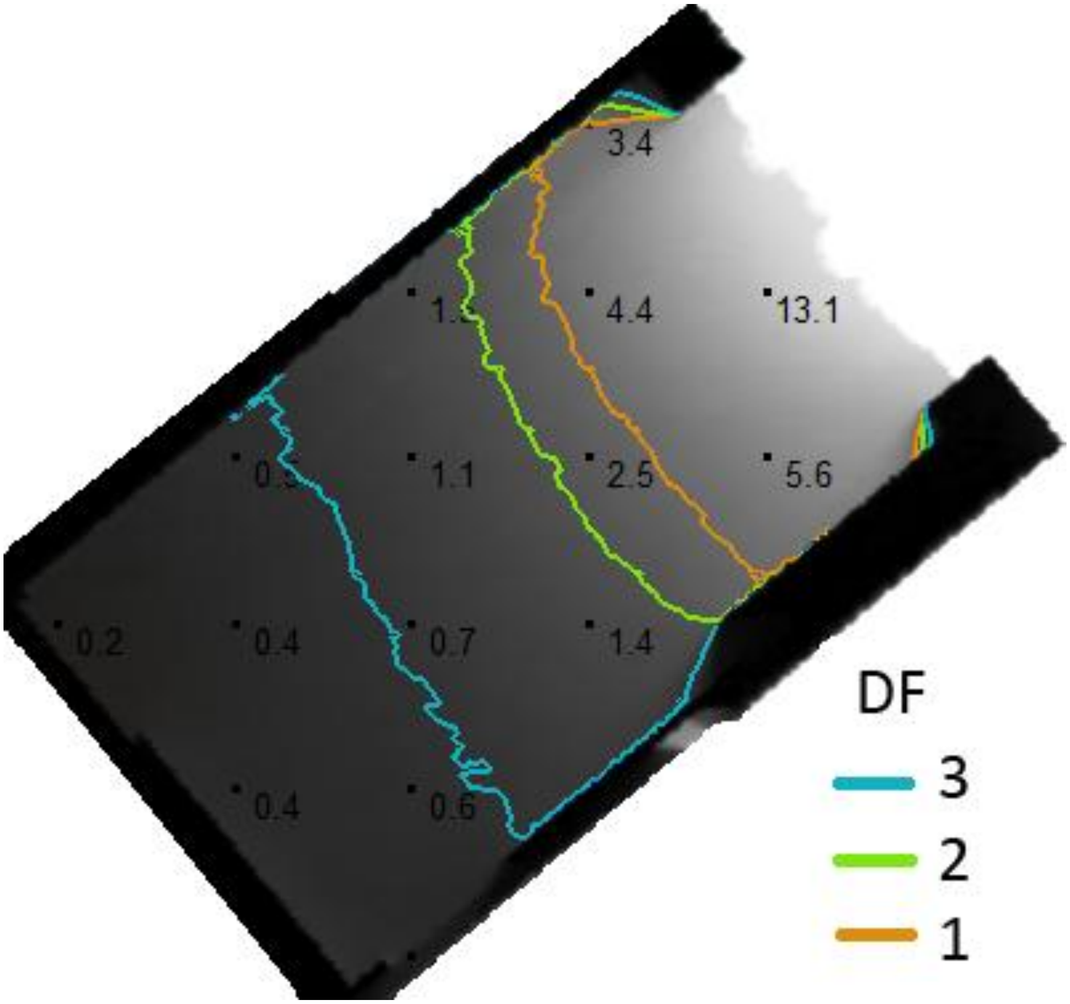
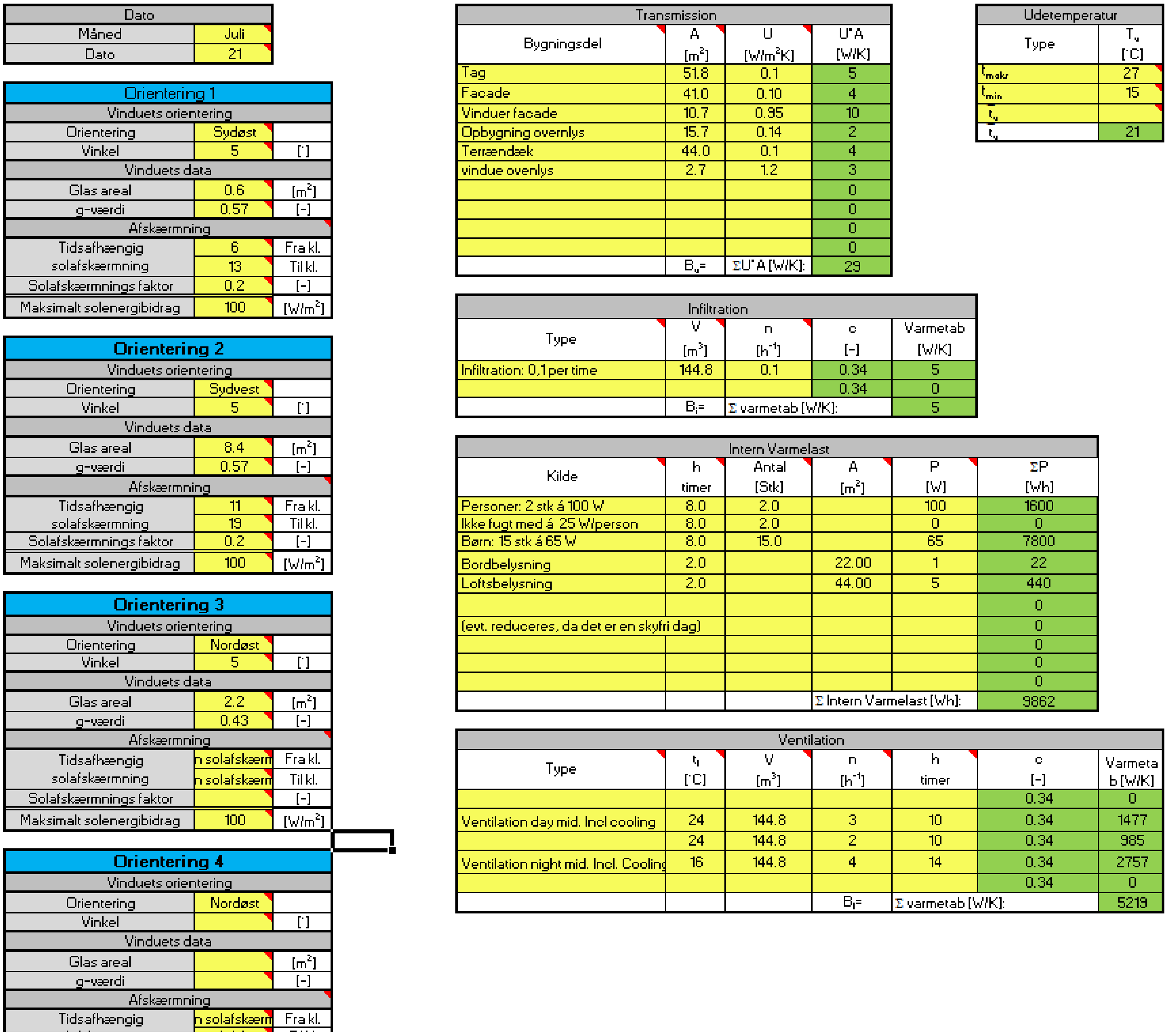


Figure 10 – Daylight factors in the office.

Appendix I – TCD

Scenario 6



Dato	
Måned	Juli
Dato	21

Orientering 1		
Vinduets orientering		
Orientering	Sydøst	
Vinkel	5	[°]
Vinduets data		
Glas areal	0.6	[m²]
g-værdi	0.57	[-]
Afskærmning		
Tidsafhængig solafskærmning	6	Fra kl.
	13	Til kl.
Solafskærmnings faktor	0.2	[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 2		
Vinduets orientering		
Orientering	Sydvest	
Vinkel	5	[°]
Vinduets data		
Glas areal	8.4	[m²]
g-værdi	0.57	[-]
Afskærmning		
Tidsafhængig solafskærmning	11	Fra kl.
	19	Til kl.
Solafskærmnings faktor	0.2	[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 3		
Vinduets orientering		
Orientering	Nordøst	
Vinkel	5	[°]
Vinduets data		
Glas areal	2.2	[m²]
g-værdi	0.43	[-]
Afskærmning		
Tidsafhængig solafskærmning	n solafskærm	Fra kl.
	n solafskærm	Til kl.
Solafskærmnings faktor		[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 4		
Vinduets orientering		
Orientering	Nordøst	
Vinkel		[°]
Vinduets data		
Glas areal		[m²]
g-værdi		[-]
Afskærmning		
Tidsafhængig	n solafskærm	Fra kl.

Transmission			
Bygningsdel	A [m²]	U [W/m²K]	U*A [W/K]
Tag	51.8	0.1	5
Facade	41.0	0.10	4
Vinduer facade	10.7	0.95	10
Opbygning overnlys	15.7	0.14	2
Terrændæk	44.0	0.1	4
vindue ovenlys	2.7	1.2	3
			0
			0
			0
			0
	B_u=	ΣU*A [W/K]:	29

Udetemperatur	
Type	T_u [°C]
t_{makr}	27
t_{min}	15
$\bar{t}_u$	
$\bar{t}_u$	21

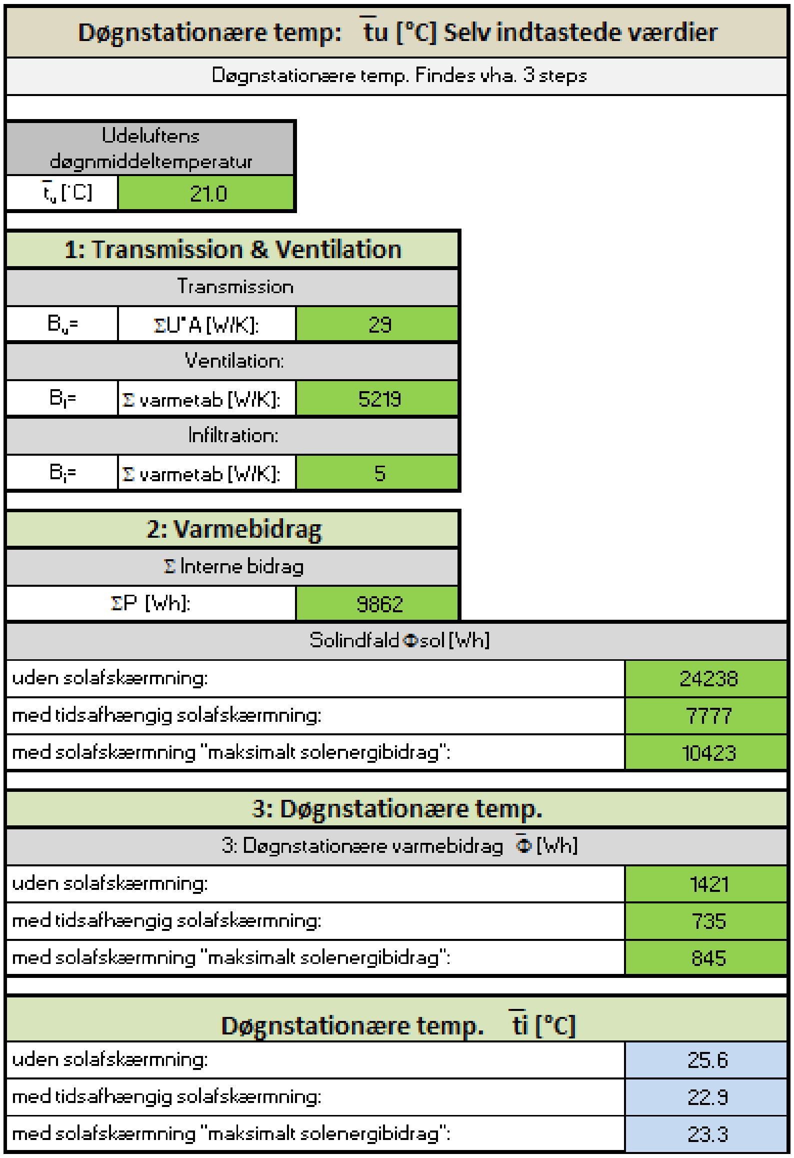
Infiltration				
Type	V [m³]	n [h⁻¹]	c [-]	Varmetab [W/K]
Infiltration: 0,1 per time	144.8	0.1	0.34	5
			0.34	0
	B_i=	Σ varmetab [W/K]:		5

Intern Varmelast					
Kilde	h timer	Antal [Stk]	A [m²]	P [W]	ΣP [Wh]
Personer: 2 stk á 100 W	8.0	2.0		100	1600
Ikke fugt med á 25 W/person	8.0	2.0		0	0
Børn: 15 stk á 65 W	8.0	15.0		65	7800
Bordbelysning	2.0		22.00	1	22
Loftsbelysning	2.0		44.00	5	440
					0
(evt. reduceres, da det er en skyfri dag)					0
					0
					0
					0
			Σ Intern Varmelast [Wh]:		9862

Ventilation						
Type	t_i [°C]	V [m³]	n [h⁻¹]	h timer	c [-]	Varmetab [W/K]
					0.34	0
Ventilation day mid. Incl cooling	24	144.8	3	10	0.34	1477
	24	144.8	2	10	0.34	985
Ventilation night mid. Incl. Cooling	16	144.8	4	14	0.34	2757
					0.34	0
			B_l=	Σ varmetab [W/K]:		5219

Figure 1 – Input values for scenario 6.

Results for scenario 6



Døgnstationære temp: $\overline{tu}$ [°C] Selv indtastede værdier

Døgnstationære temp. Findes vha. 3 steps

Udeluftens døgnmiddeltemperatur	
$\bar{t}_u$ [°C]	21.0

1: Transmission & Ventilation

Transmission		
B_u=	ΣU*A [W/K]:	29
Ventilation:		
B_l=	Σ varmetab [W/K]:	5219
Infiltration:		
B_i=	Σ varmetab [W/K]:	5

2: Varmebidrag

Σ Interne bidrag	
ΣP [Wh]:	9862

Solindfald Φsol [Wh]	
uden solafskærmning:	24238
med tidsafhængig solafskærmning:	7777
med solafskærmning "maksimalt solenergibidrag":	10423

3: Døgnstationære temp.

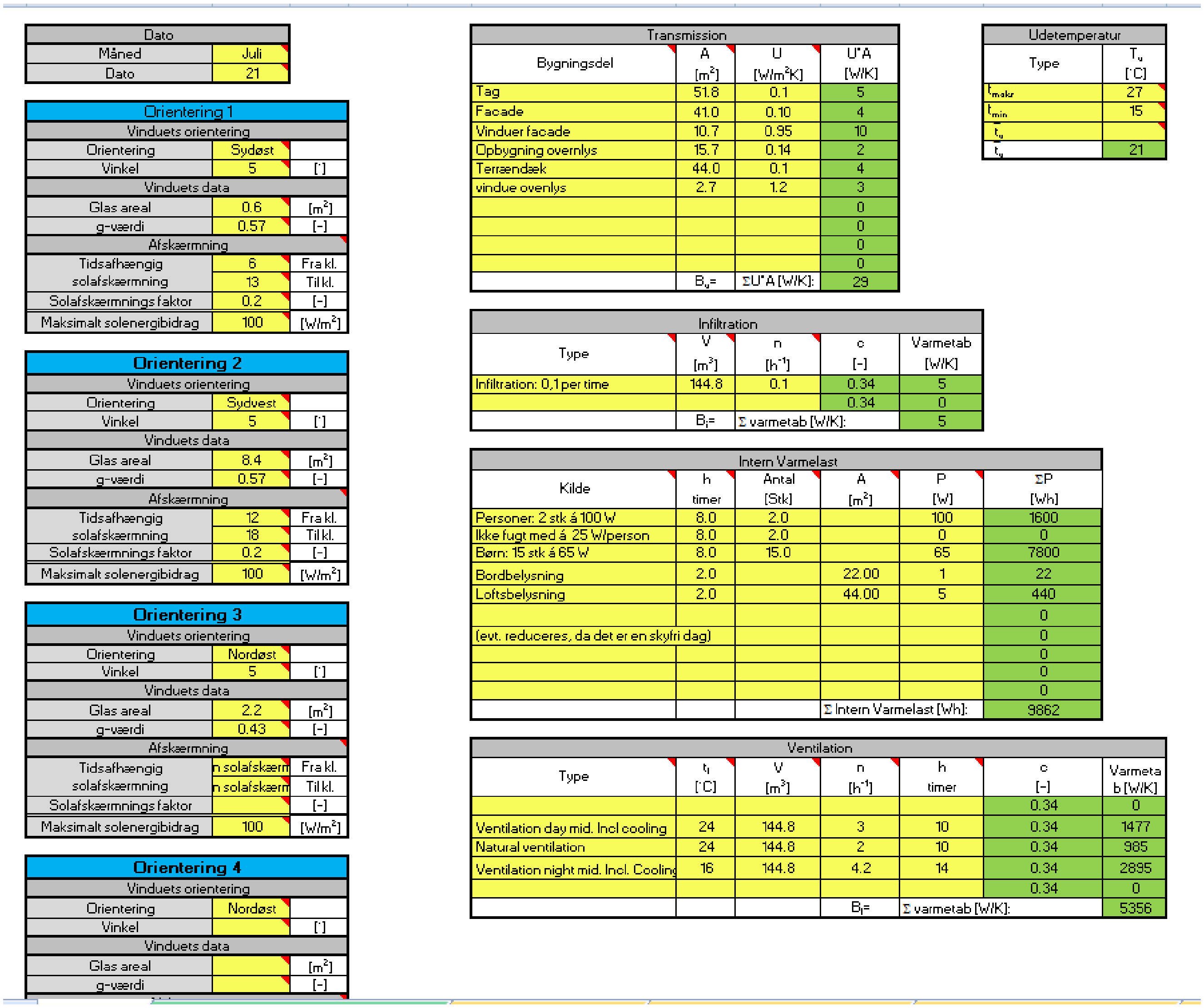
3: Døgnstationære varmebidrag $\bar{\Phi}$ [Wh]	
uden solafskærmning:	1421
med tidsafhængig solafskærmning:	735
med solafskærmning "maksimalt solenergibidrag":	845

Døgnstationære temp. $\overline{ti}$ [°C]

uden solafskærmning:	25.6
med tidsafhængig solafskærmning:	22.9
med solafskærmning "maksimalt solenergibidrag":	23.3

Figure 2 – Results of scenario 6.

Scenario 7



Dato	
Måned	Juli
Dato	21

Orientering 1		
Vinduets orientering		
Orientering	Sydøst	
Vinkel	5	[°]
Vinduets data		
Glas areal	0.6	[m²]
g-værdi	0.57	[-]
Afskærmning		
Tidsafhængig solafskærmning	6	Fra kl.
	13	Til kl.
Solafskærmnings faktor	0.2	[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 2		
Vinduets orientering		
Orientering	Sydvest	
Vinkel	5	[°]
Vinduets data		
Glas areal	8.4	[m²]
g-værdi	0.57	[-]
Afskærmning		
Tidsafhængig solafskærmning	12	Fra kl.
	18	Til kl.
Solafskærmnings faktor	0.2	[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 3		
Vinduets orientering		
Orientering	Nordøst	
Vinkel	5	[°]
Vinduets data		
Glas areal	2.2	[m²]
g-værdi	0.43	[-]
Afskærmning		
Tidsafhængig solafskærmning	n solafskærm	Fra kl.
	n solafskærm	Til kl.
Solafskærmnings faktor		[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 4		
Vinduets orientering		
Orientering	Nordøst	
Vinkel		[°]
Vinduets data		
Glas areal		[m²]
g-værdi		[-]

Transmission			
Bygningsdel	A [m²]	U [W/m²K]	U*A [W/K]
Tag	51.8	0.1	5
Facade	41.0	0.10	4
Vinduer facade	10.7	0.95	10
Opbygning overnlys	15.7	0.14	2
Terrændæk	44.0	0.1	4
vindue ovenlys	2.7	1.2	3
			0
			0
			0
			0
	B_u=	ΣU*A [W/K]:	29

Udetemperatur	
Type	T_u [°C]
t_{makr}	27
t_{min}	15
$\bar{t}_u$	
$\bar{t}_v$	21

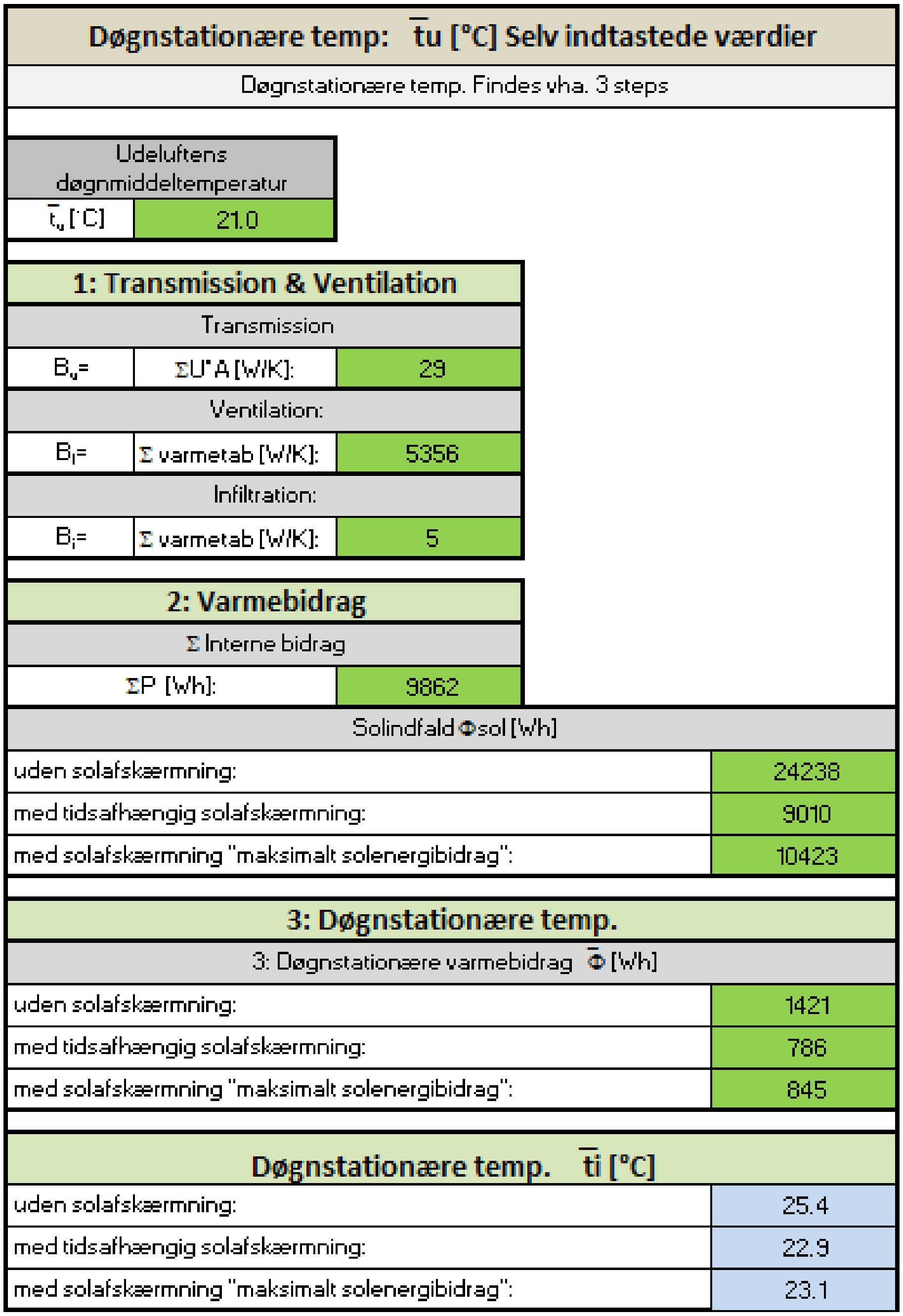
Infiltration				
Type	V [m³]	n [h⁻¹]	c [-]	Varmetab [W/K]
Infiltration: 0,1 per time	144.8	0.1	0.34	5
			0.34	0
	B_i=	Σ varmetab [W/K]:		5

Intern Varmelast					
Kilde	h timer	Antal [Stk]	A [m²]	P [W]	ΣP [Wh]
Personer: 2 stk á 100 W	8.0	2.0		100	1600
Ikke fugt med á 25 W/person	8.0	2.0		0	0
Børn: 15 stk á 65 W	8.0	15.0		65	7800
Bordbelysning	2.0		22.00	1	22
Loftsbelysning	2.0		44.00	5	440
					0
(evt. reduceres, da det er en skyfri dag)					0
					0
					0
					0
			Σ Intern Varmelast [Wh]:		9862

Ventilation						
Type	t_i [°C]	V [m³]	n [h⁻¹]	h timer	c [-]	Varmetab [W/K]
					0.34	0
Ventilation day mid. Incl cooling	24	144.8	3	10	0.34	1477
Natural ventilation	24	144.8	2	10	0.34	985
Ventilation night mid. Incl. Cooling	16	144.8	4.2	14	0.34	2895
					0.34	0
			B_l=	Σ varmetab [W/K]:		5356

Figure 3 – Inputs for scenario 7.

Results scenario 7



Døgnstationære temp: $\bar{t}u$ [°C] Selv indtastede værdier

Døgnstationære temp. Findes vha. 3 steps

Udeluftens døgnmiddeltemperatur	
$\bar{t}_u$ [°C]	21.0

1: Transmission & Ventilation

Transmission		
B_v=	ΣU*A [W/K]:	29
Ventilation:		
B_l=	Σ varmetab [W/K]:	5356
Infiltration:		
B_i=	Σ varmetab [W/K]:	5

2: Varmebidrag

Σ Interne bidrag	
ΣP [Wh]:	9862

Solindfald Φsol [Wh]	
uden solafskærmning:	24238
med tidsafhængig solafskærmning:	9010
med solafskærmning "maksimalt solenergibidrag":	10423

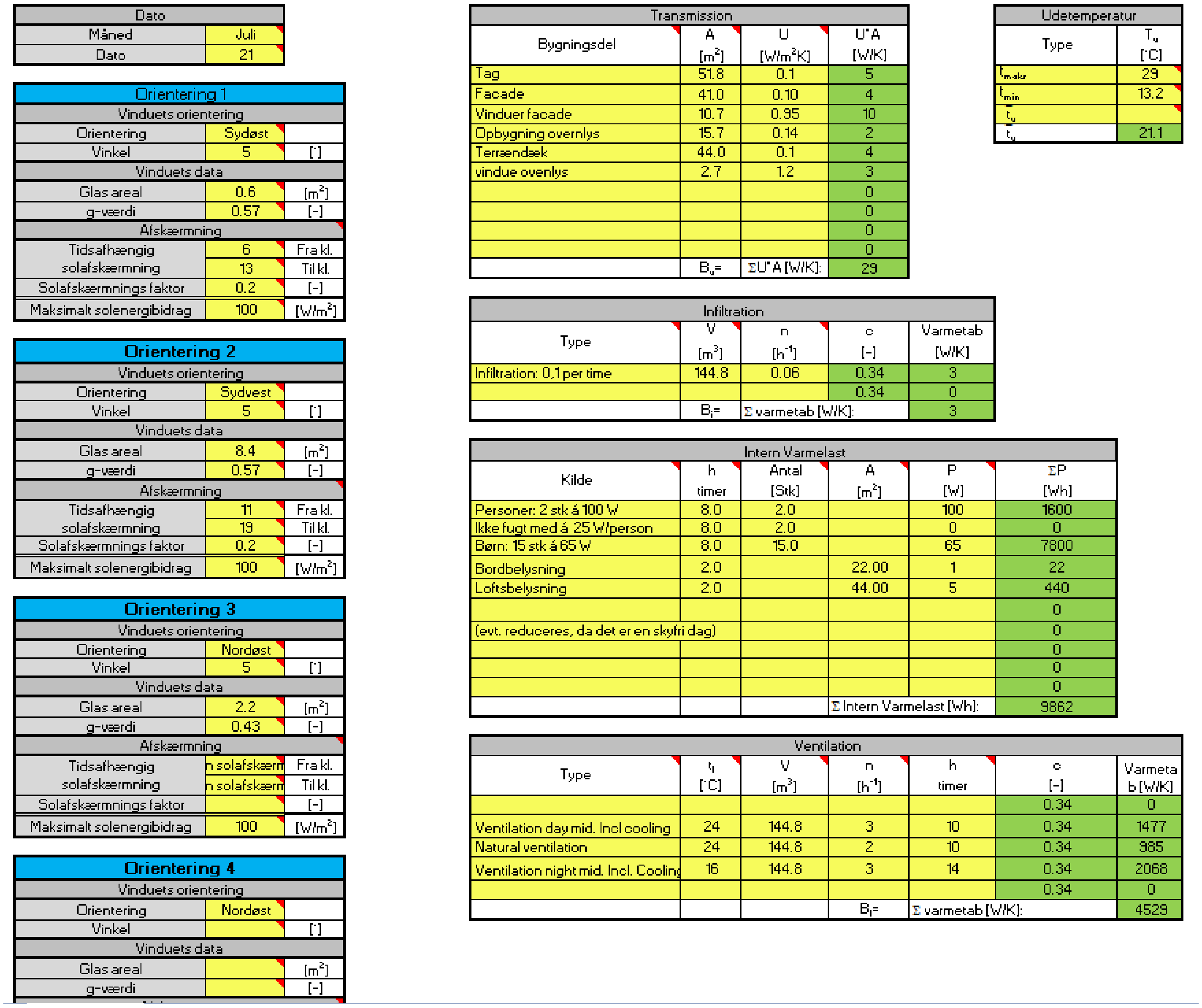
3: Døgnstationære temp.

3: Døgnstationære varmebidrag $\bar{\Phi}$ [Wh]	
uden solafskærmning:	1421
med tidsafhængig solafskærmning:	786
med solafskærmning "maksimalt solenergibidrag":	845

Døgnstationære temp. $\bar{t}i$ [°C]	
uden solafskærmning:	25.4
med tidsafhængig solafskærmning:	22.9
med solafskærmning "maksimalt solenergibidrag":	23.1

Figure 4 – Results of scenario 7.

Scenario 8



Dato	
Måned	Juli
Dato	21

Orientering 1		
Vinduets orientering		
Orientering	Sydøst	
Vinkel	5	[°]
Vinduets data		
Glas areal	0.6	[m²]
g-værdi	0.57	[-]
Afskærmning		
Tidsafhængig solafskærmning	6	Fra kl.
	13	Til kl.
Solafskærmnings faktor	0.2	[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 2		
Vinduets orientering		
Orientering	Sydvest	
Vinkel	5	[°]
Vinduets data		
Glas areal	8.4	[m²]
g-værdi	0.57	[-]
Afskærmning		
Tidsafhængig solafskærmning	11	Fra kl.
	19	Til kl.
Solafskærmnings faktor	0.2	[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 3		
Vinduets orientering		
Orientering	Nordøst	
Vinkel	5	[°]
Vinduets data		
Glas areal	2.2	[m²]
g-værdi	0.43	[-]
Afskærmning		
Tidsafhængig solafskærmning	n solafskærm	Fra kl.
	n solafskærm	Til kl.
Solafskærmnings faktor		[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 4		
Vinduets orientering		
Orientering	Nordøst	
Vinkel		[°]
Vinduets data		
Glas areal		[m²]
g-værdi		[-]

Transmission			
Bygningsdel	A [m²]	U [W/m²K]	U*A [W/K]
Tag	51.8	0.1	5
Facade	41.0	0.10	4
Vinduer facade	10.7	0.95	10
Opbygning overnlys	15.7	0.14	2
Terrændæk	44.0	0.1	4
vindue ovenlys	2.7	1.2	3
			0
			0
			0
			0
	B_u=	ΣU*A [W/K]:	29

Udetemperatur	
Type	T_u [°C]
t_{makr}	29
t_{min}	13.2
$\bar{t}_u$	
$\bar{t}_u$	21.1

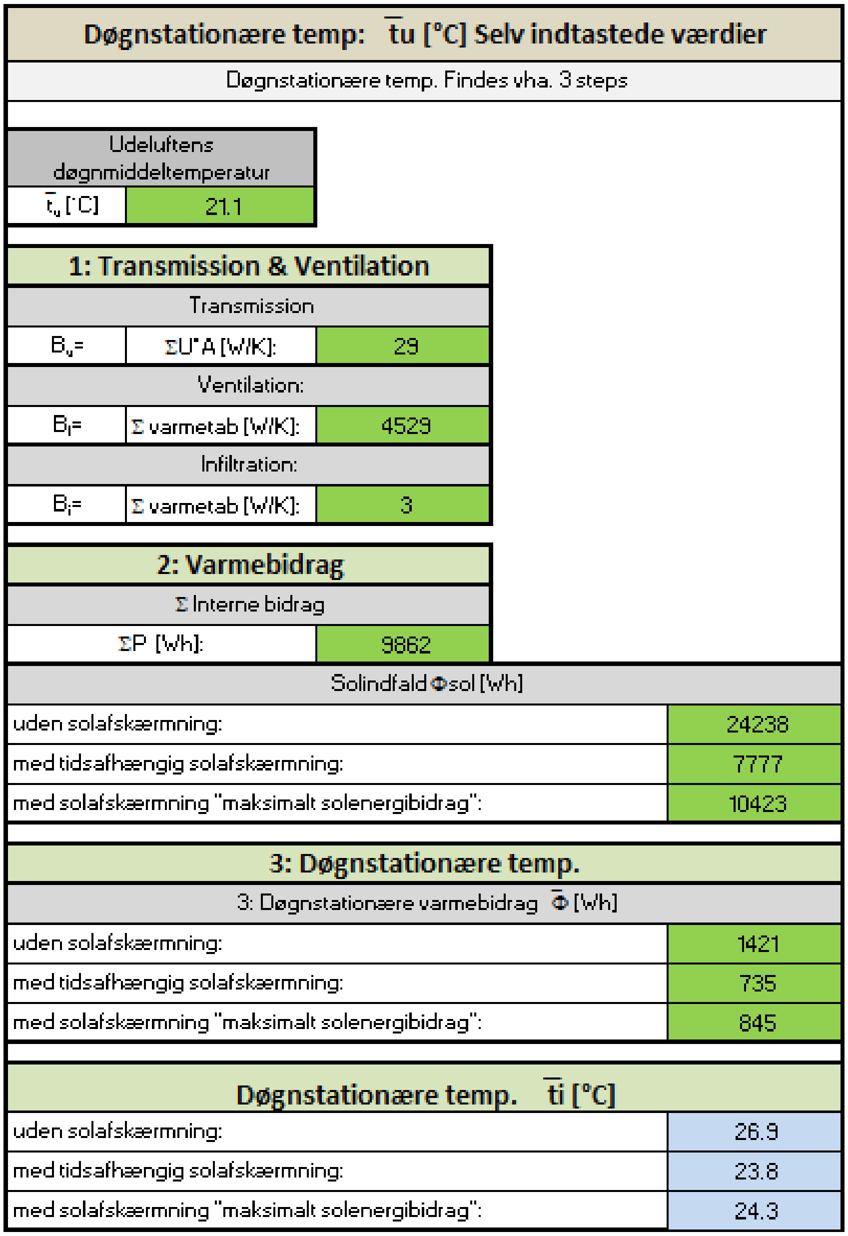
Infiltration				
Type	V [m³]	n [h⁻¹]	c [-]	Varmetab [W/K]
Infiltration: 0,1 per time	144.8	0.06	0.34	3
			0.34	0
	B_i=	Σ varmetab [W/K]:		3

Intern Varmelast					
Kilde	h timer	Antal [Stk]	A [m²]	P [W]	ΣP [Wh]
Personer: 2 stk á 100 W	8.0	2.0		100	1600
Ikke fugt med á 25 W/person	8.0	2.0		0	0
Børn: 15 stk á 65 W	8.0	15.0		65	7800
Bordbelysning	2.0		22.00	1	22
Loftsbelysning	2.0		44.00	5	440
					0
(evt. reduceres, da det er en skyfri dag)					0
					0
					0
					0
			Σ Intern Varmelast [Wh]:		9862

Ventilation						
Type	t_i [°C]	V [m³]	n [h⁻¹]	h timer	c [-]	Varmetab [W/K]
					0.34	0
Ventilation day mid. Incl cooling	24	144.8	3	10	0.34	1477
Natural ventilation	24	144.8	2	10	0.34	985
Ventilation night mid. Incl. Cooling	16	144.8	3	14	0.34	2068
					0.34	0
			B_i=	Σ varmetab [W/K]:		4529

Figure 5 – Inputs for scenario 8.

Results scenario 8



Døgnstationære temp: $\overline{tu}$ [°C] Selv indtastede værdier

Døgnstationære temp. Findes vha. 3 steps

Udeluftens døgnmiddeltemperatur	
$\bar{t}_u$ [°C]	21.1

1: Transmission & Ventilation

Transmission		
B_v=	ΣU*A [W/K]:	29
Ventilation:		
B_l=	Σ varmetab [W/K]:	4529
Infiltration:		
B_i=	Σ varmetab [W/K]:	3

2: Varmebidrag

Σ Interne bidrag	
ΣP [Wh]:	9862

Solindfald Φsol [Wh]	
uden solafskærmning:	24238
med tidsafhængig solafskærmning:	7777
med solafskærmning "maksimalt solenergibidrag":	10423

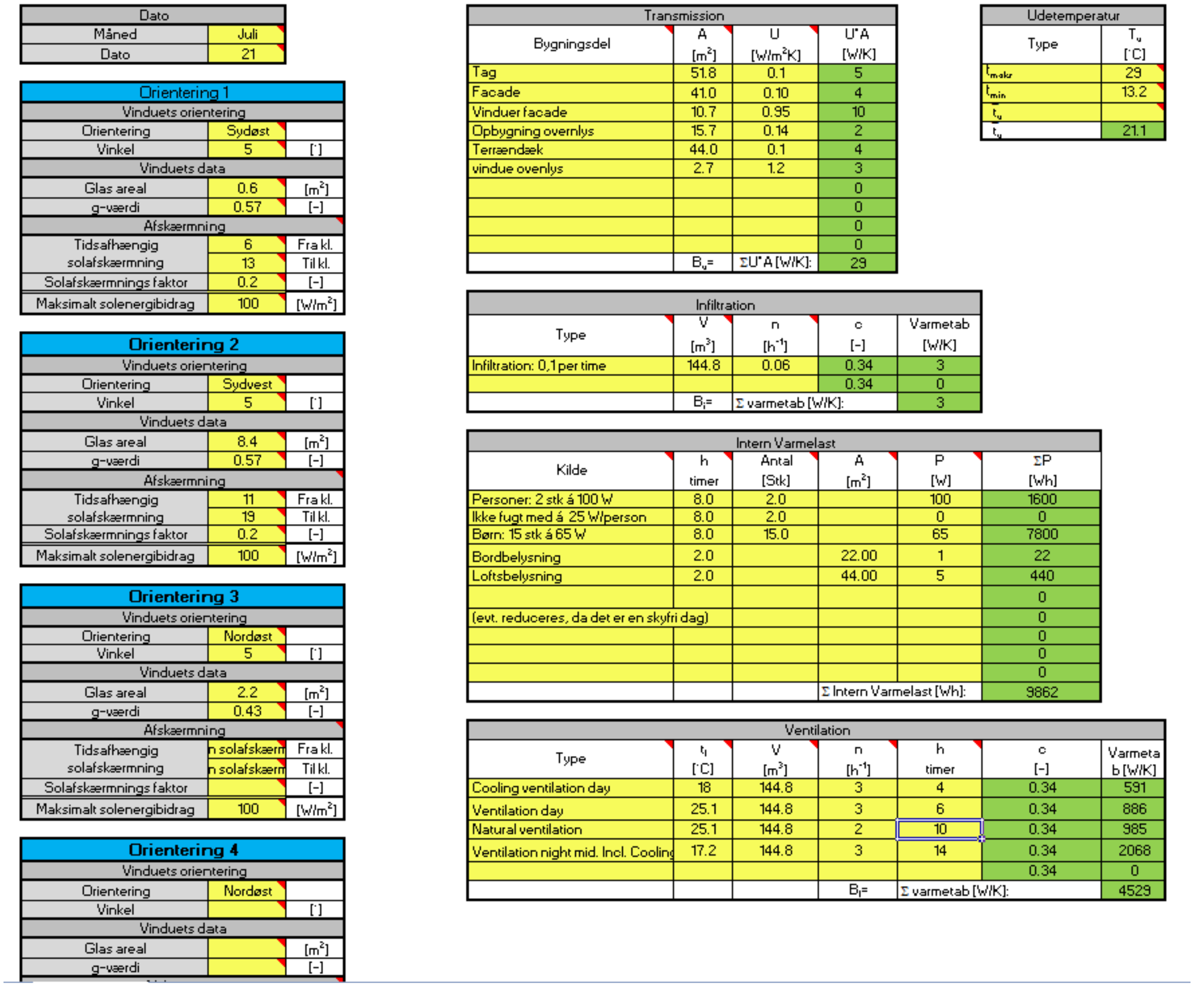
3: Døgnstationære temp.

3: Døgnstationære varmebidrag $\bar{\Phi}$ [Wh]	
uden solafskærmning:	1421
med tidsafhængig solafskærmning:	735
med solafskærmning "maksimalt solenergibidrag":	845

Døgnstationære temp. $\overline{ti}$ [°C]	
uden solafskærmning:	26.9
med tidsafhængig solafskærmning:	23.8
med solafskærmning "maksimalt solenergibidrag":	24.3

Figure 6 – Results of scenario 8.

Tailored TCD scenario



Dato	
Måned	Juli
Dato	21

Orientering 1		
Vinduets orientering		
Orientering	Sydøst	
Vinkel	5	[°]
Vinduets data		
Glas areal	0.6	[m²]
g-værdi	0.57	[-]
Afskærmning		
Tidsafhængig solafskærmning	6	Fra kl.
	13	Til kl.
Solafskærmnings faktor	0.2	[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 2		
Vinduets orientering		
Orientering	Sydvest	
Vinkel	5	[°]
Vinduets data		
Glas areal	8.4	[m²]
g-værdi	0.57	[-]
Afskærmning		
Tidsafhængig solafskærmning	11	Fra kl.
	19	Til kl.
Solafskærmnings faktor	0.2	[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 3		
Vinduets orientering		
Orientering	Nordøst	
Vinkel	5	[°]
Vinduets data		
Glas areal	2.2	[m²]
g-værdi	0.43	[-]
Afskærmning		
Tidsafhængig solafskærmning	n solafskærm	Fra kl.
	n solafskærm	Til kl.
Solafskærmnings faktor		[-]
Maksimalt solenergibidrag	100	[W/m²]

Orientering 4		
Vinduets orientering		
Orientering	Nordøst	
Vinkel		[°]
Vinduets data		
Glas areal		[m²]
g-værdi		[-]

Transmission			
Bygningsdel	A [m²]	U [W/m²K]	U*A [W/K]
Tag	51.8	0.1	5
Facade	41.0	0.10	4
Vinduer facade	10.7	0.95	10
Opbygning overnlys	15.7	0.14	2
Terrændæk	44.0	0.1	4
vindue ovenlys	2.7	1.2	3
			0
			0
			0
			0
	B_u=	ΣU*A [W/K]:	29

Udetemperatur	
Type	T_u [°C]
t_{maks}	29
t_{min}	13.2
t_u	
t_u	21.1

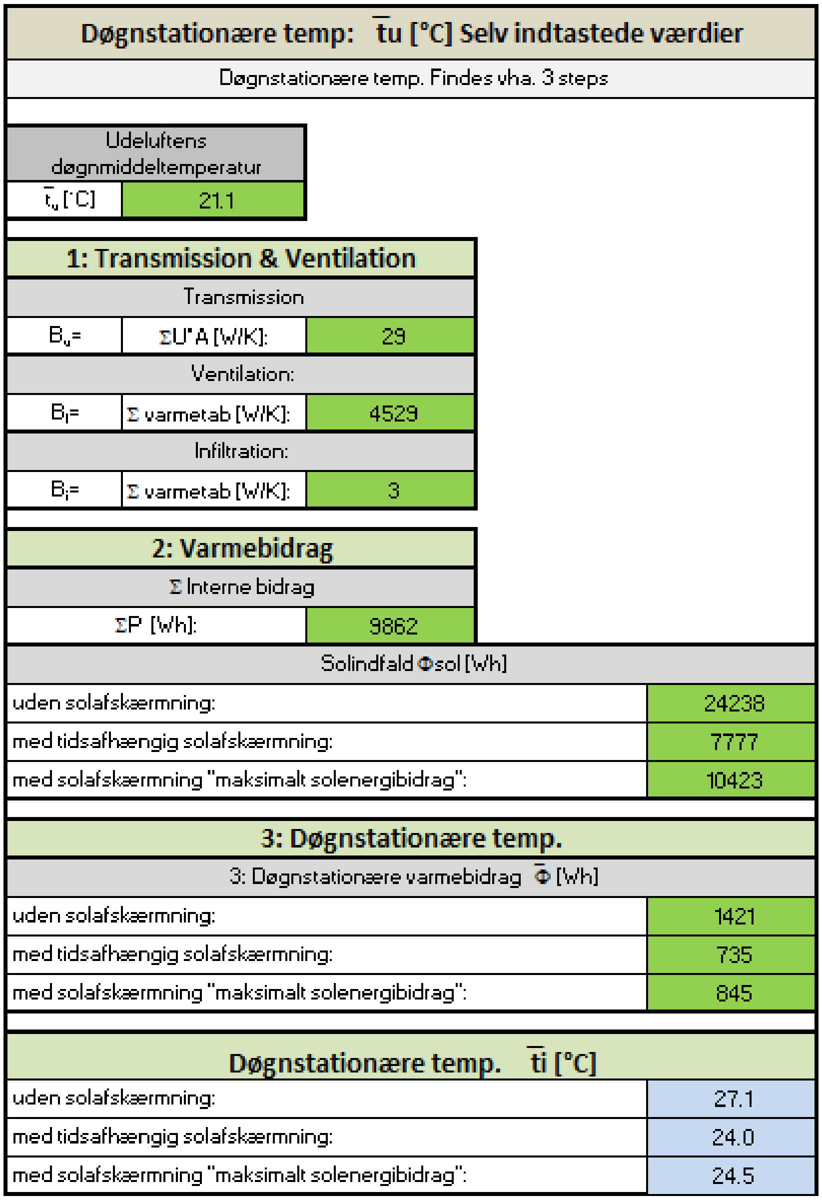
Infiltration				
Type	V [m³]	n [h⁻¹]	c [-]	Varmetab [W/K]
Infiltration: 0,1 per time	144.8	0.06	0.34	3
			0.34	0
	B_i=	Σ varmetab [W/K]:		3

Intern Varmelast					
Kilde	h timer	Antal [Stk]	A [m²]	P [W]	ΣP [Wh]
Personer: 2 stk á 100 W	8.0	2.0		100	1600
Ikke fugt med á 25 W/person	8.0	2.0		0	0
Børn: 15 stk á 65 W	8.0	15.0		65	7800
Bordbelysning	2.0		22.00	1	22
Loftsbelysning	2.0		44.00	5	440
					0
(evt. reduceres, da det er en skyfri dag)					0
					0
					0
					0
			Σ Intern Varmelast [Wh]:		9862

Ventilation						
Type	t_i [°C]	V [m³]	n [h⁻¹]	h timer	c [-]	Varmetab [W/K]
Cooling ventilation day	18	144.8	3	4	0.34	591
Ventilation day	25.1	144.8	3	6	0.34	886
Natural ventilation	25.1	144.8	2	10	0.34	985
Ventilation night mid. Incl. Cooling	17.2	144.8	3	14	0.34	2068
					0.34	0
			B_i=	Σ varmetab [W/K]:		4529

Figure 7 – Inputs for Tailored TCD scenario.

Results of Tailored TCD scenario



Døgnstationære temp: $\overline{tu}$ [°C] Selv indtastede værdier

Døgnstationære temp. Findes vha. 3 steps

Udeluftens døgnmiddeltemperatur	
$\bar{t}_u$ [°C]	21.1

1: Transmission & Ventilation

Transmission		
B_v=	ΣU*A [W/K]:	29
Ventilation:		
B_l=	Σ varmetab [W/K]:	4529
Infiltration:		
B_i=	Σ varmetab [W/K]:	3

2: Varmebidrag

Σ Interne bidrag	
ΣP [Wh]:	9862

Solindfald Φsol [Wh]	
uden solafskærmning:	24238
med tidsafhængig solafskærmning:	7777
med solafskærmning "maksimalt solenergibidrag":	10423

3: Døgnstationære temp.

3: Døgnstationære varmebidrag $\bar{\Phi}$ [Wh]	
uden solafskærmning:	1421
med tidsafhængig solafskærmning:	735
med solafskærmning "maksimalt solenergibidrag":	845

Døgnstationære temp. $\overline{ti}$ [°C]	
uden solafskærmning:	27.1
med tidsafhængig solafskærmning:	24.0
med solafskærmning "maksimalt solenergibidrag":	24.5

Figure 8 – Results of Tailored TCD scenario.

Appendix J – Growth charts [Sundhedsguiden]

Growth charts for children 1-12 years.

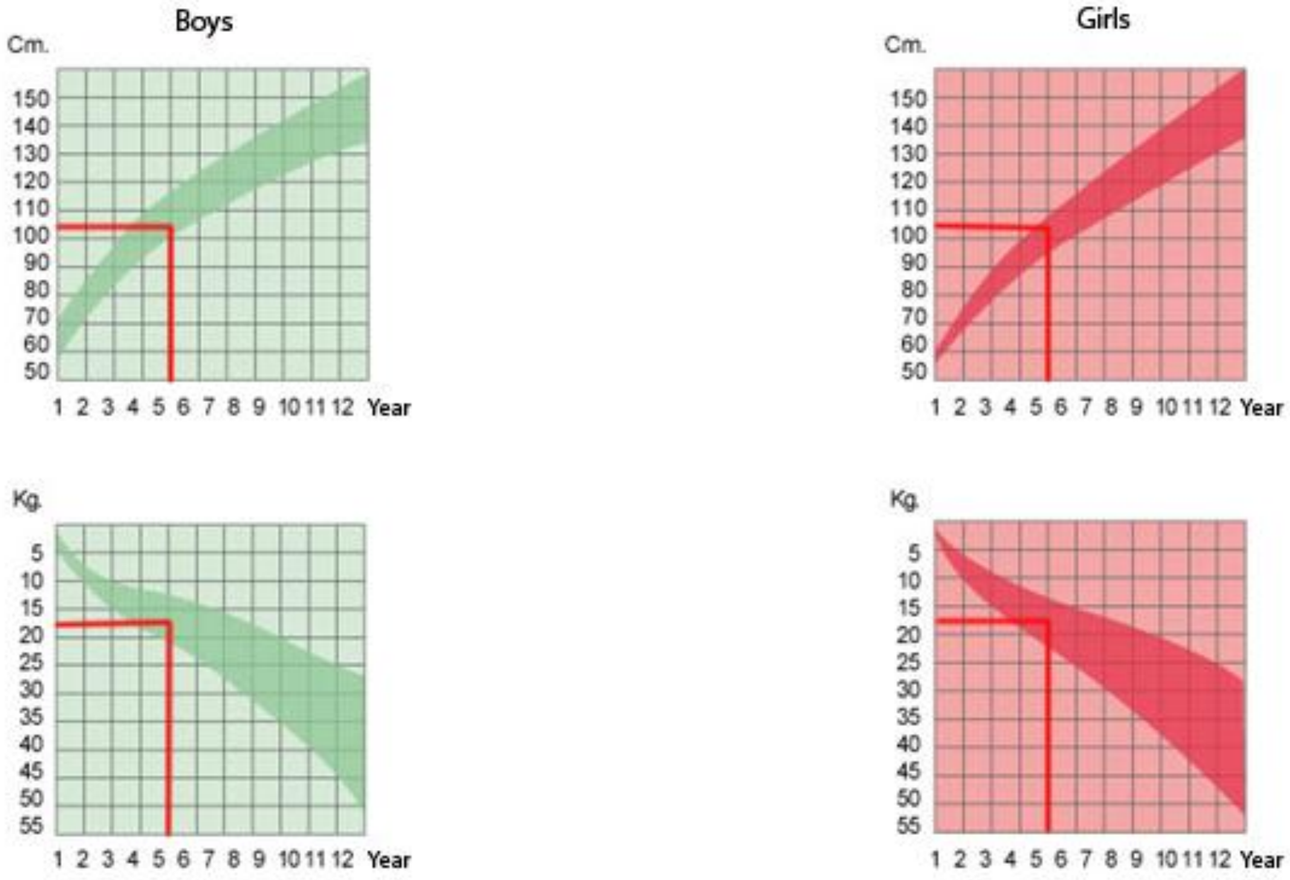


Figure 1 - The children in the youngest part of the daycare institution is assumed to be an average of 5 years old. This gives an average between boys and girls together a height of approx. 105 cm and approx. 17 kg.

Appendix K - Bsim results

Thermal indoor climate simulated in Bsim during summer June – August.

Scenario 1: External sunscreen; ventilation (VAV): 6h^{-1} always + 2h^{-1} natural vent.; **NO mechanical cooling**.

Overheating hours: **> 26°C: 76 hours; > 27°C: 48 hours** – **Does not comply with the thermal requirements of BR10.**

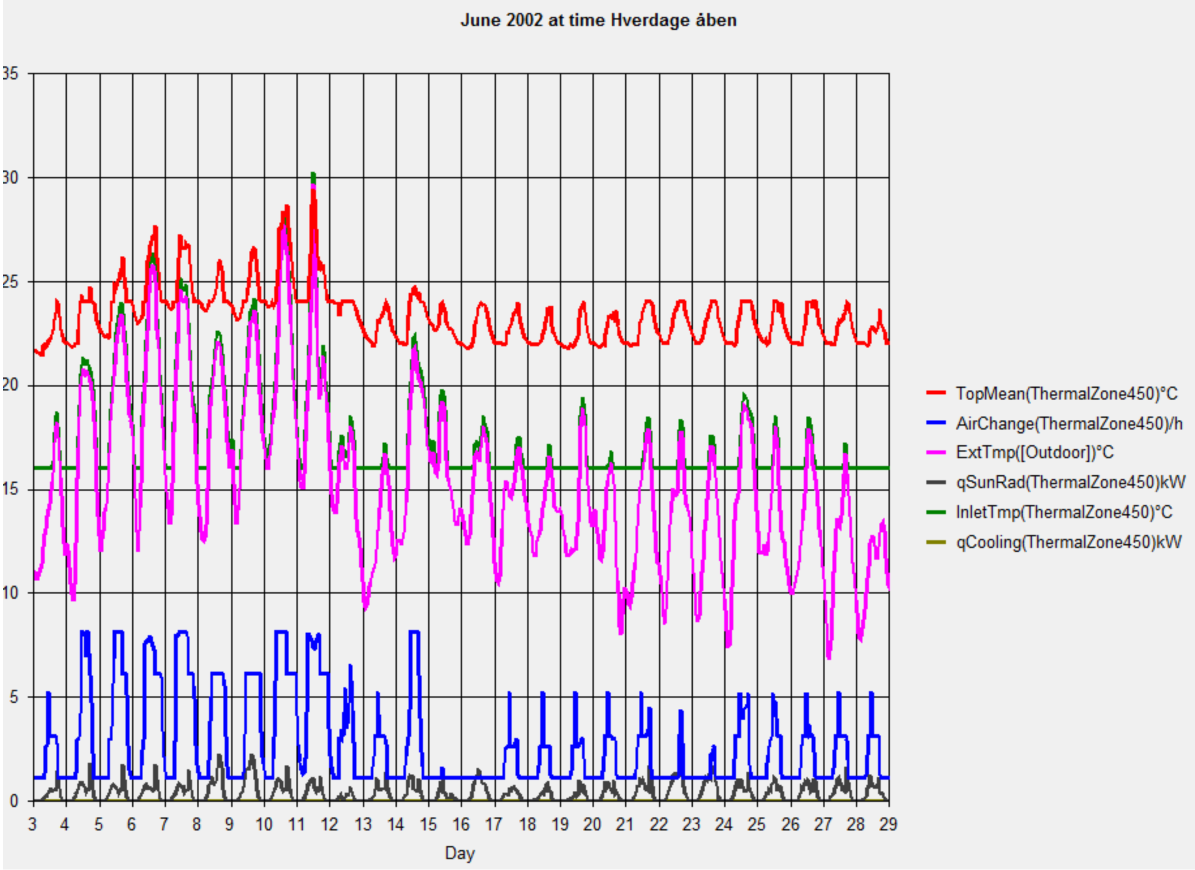
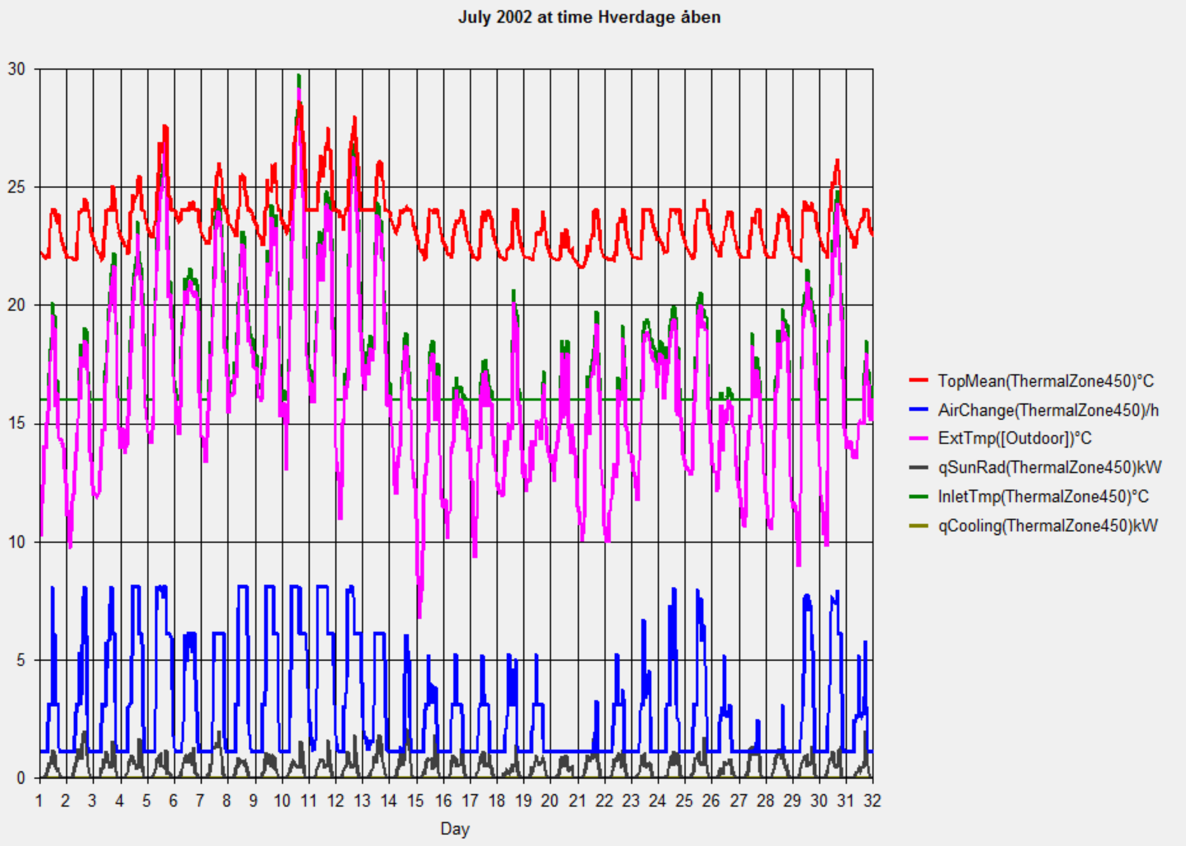


Figure 1 – Scenario 1 – June.



Scenario 1: **External sunscreen**; ventilation (VAV): 6h^{-1} always + 2 h^{-1} natural vent.; **NO mechanical cooling**.

Figure 2 – Scenario 1 – July.

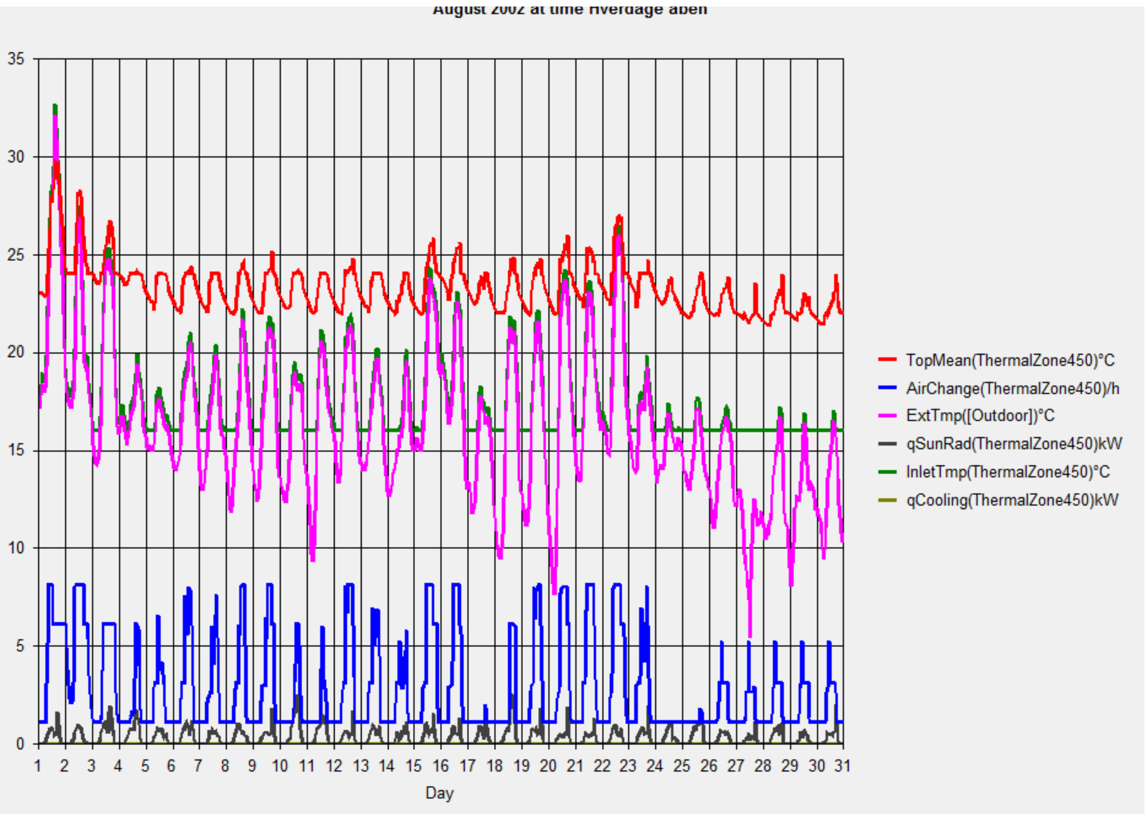


Figure 3 – Scenario 1 – August.

Figure 1, 2 and 3 shows that at peak situations with a high solar radiation and high exterior temperatures, the VAV 6h^{-1} mechanical vent. + 2h^{-1}natural ventilation and no cooling cannot keep the temperatures low enough during the summer months. (The air change graphs in all figures are a combination of mechanical and natural ventilation where the latter represent 2h^{-1} see more on this in figure 10).

Scenario 2: **External sunscreen**; ventilation (VAV): 3h^{-1} summer nights + 3h^{-1} open hours all year + 1h^{-1} always + 2h^{-1} natural vent.; **cooling load: -0,5 kW (11.3 W/m^2)**.

Overheating hours: **> 26°C: 71 hours; > 27°C: 25 hours** - Just complies with the thermal requirements of BR10.

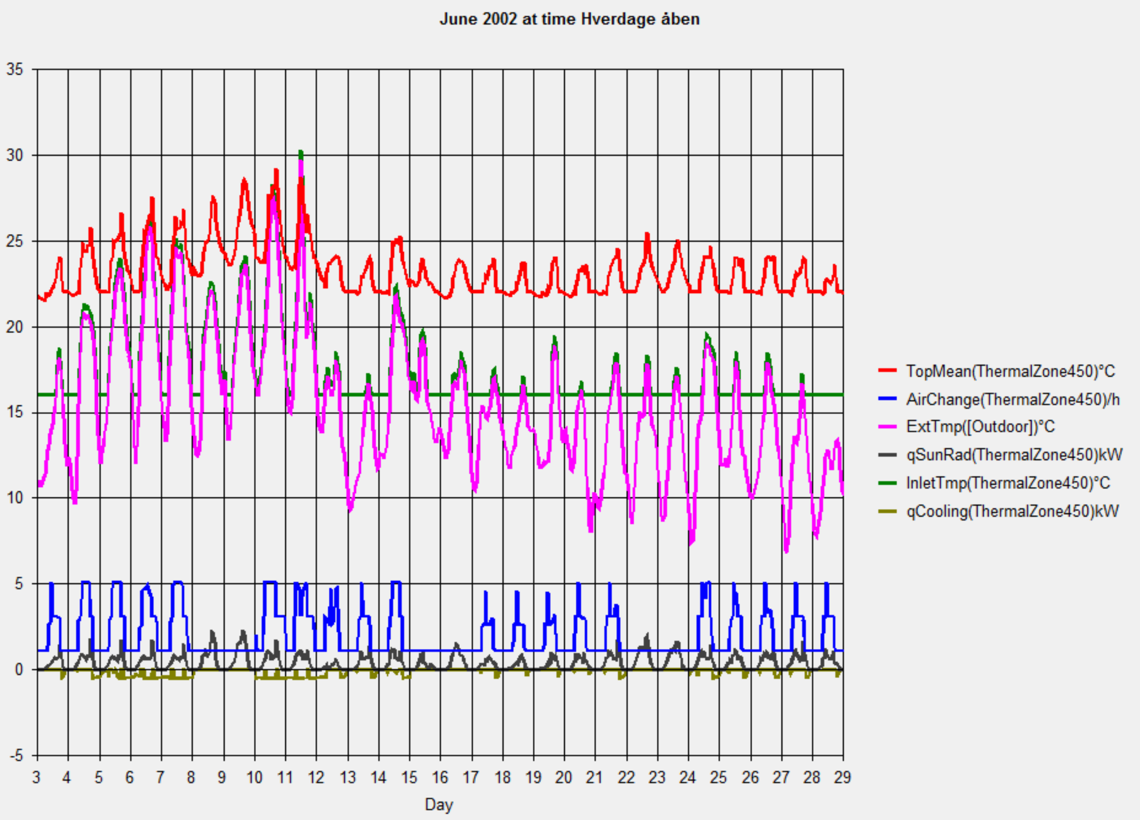


Figure 4 – Scenario 2 - June (the 8th and the 9th are weekend, hence the low air change (1h^{-1})).

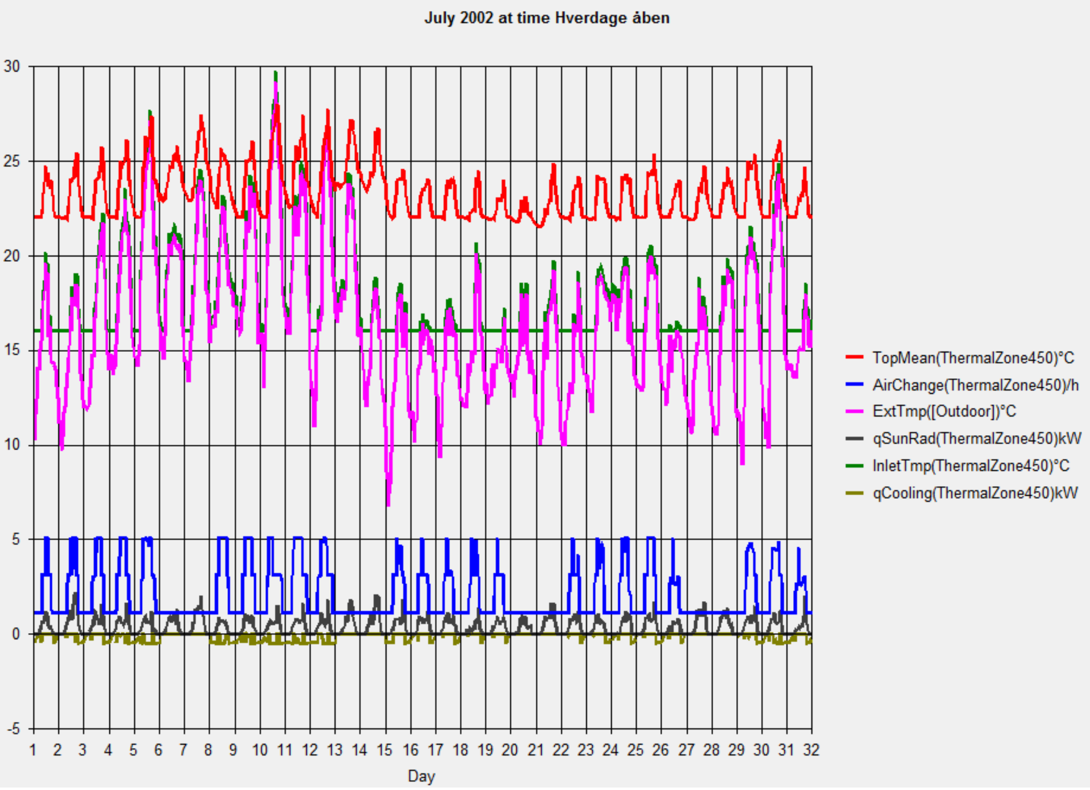


Figure 5 – Scenario 2 – July.

Scenario 2: **External sunscreen**; ventilation (VAV): 3h^{-1} summer nights + 3h^{-1} open hours all year + 1h^{-1} always + 2h^{-1} natural vent.; **cooling load: -0,5 kW (11.3 W/m^{2})**.

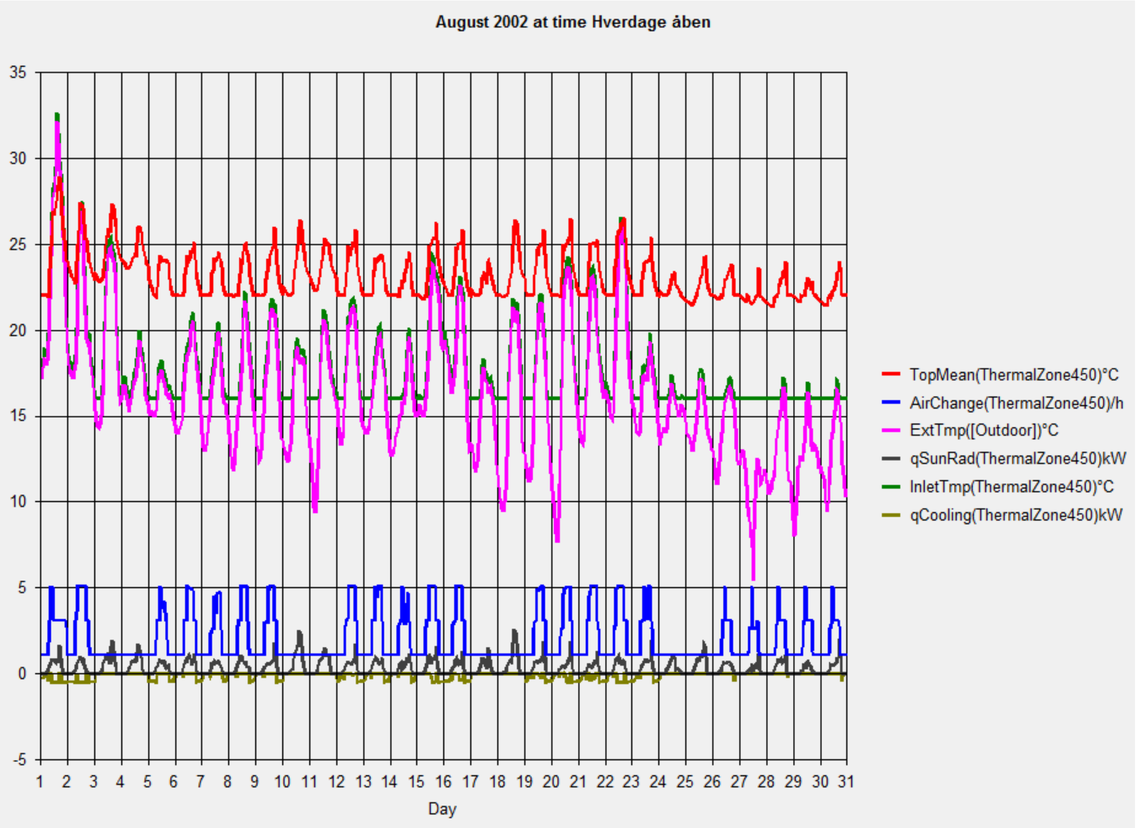


Figure 6 – Scenario 2 – August.

Figure 4, 5 and 6 shows internal temperatures in the low and mid 20´ties for the most part and som peak values above this. Avoiding any temperatures above the mid 20'ties completely requires a high ventilation rate and even more cooling with high exterior temperatures. In scenario 2 alternative in figure 13 it is illustrated how much cooling is required to avoid temperatures above 26 °C in week 28 (2nd week in July). But in this scenario 2, rather than dimensioning the air handling unit for a few peak situations, when this ventilation strategy already complies with BR10, the few overheating hours are accepted here, because the building is a daycare institution where occupants can freily go in and out as they please unlike for instance an office.

Scenario 3: **Internal sunblind**; ventilation (VAV):): 3h^{-1} summer nights + 3h^{-1} open hours all year + 1h^{-1} always + 2h^{-1} natural ventilation; **cooling load: -1 kW (22.6 W/m^2)**.
Overheating hours: **> 26°C: 81 hours; > 23 °C: 36 hours** – Scenario does not comply with BR10.

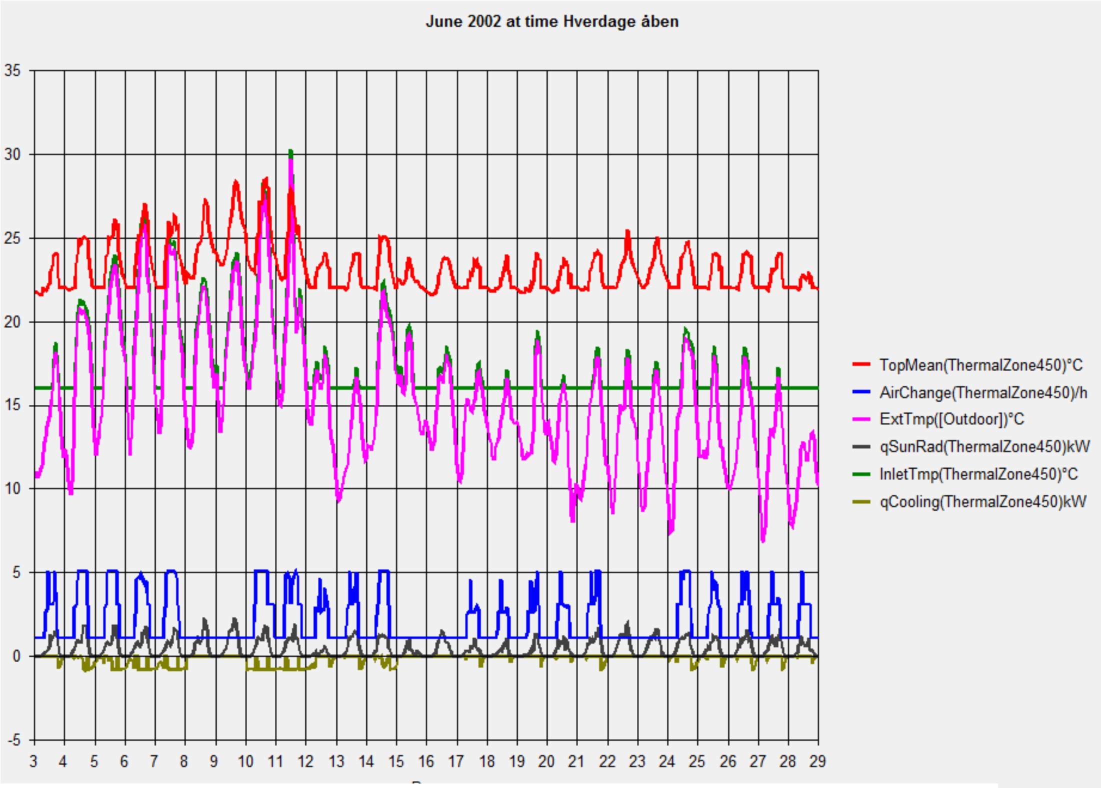


Figure 7 – Scenario 3 – June.

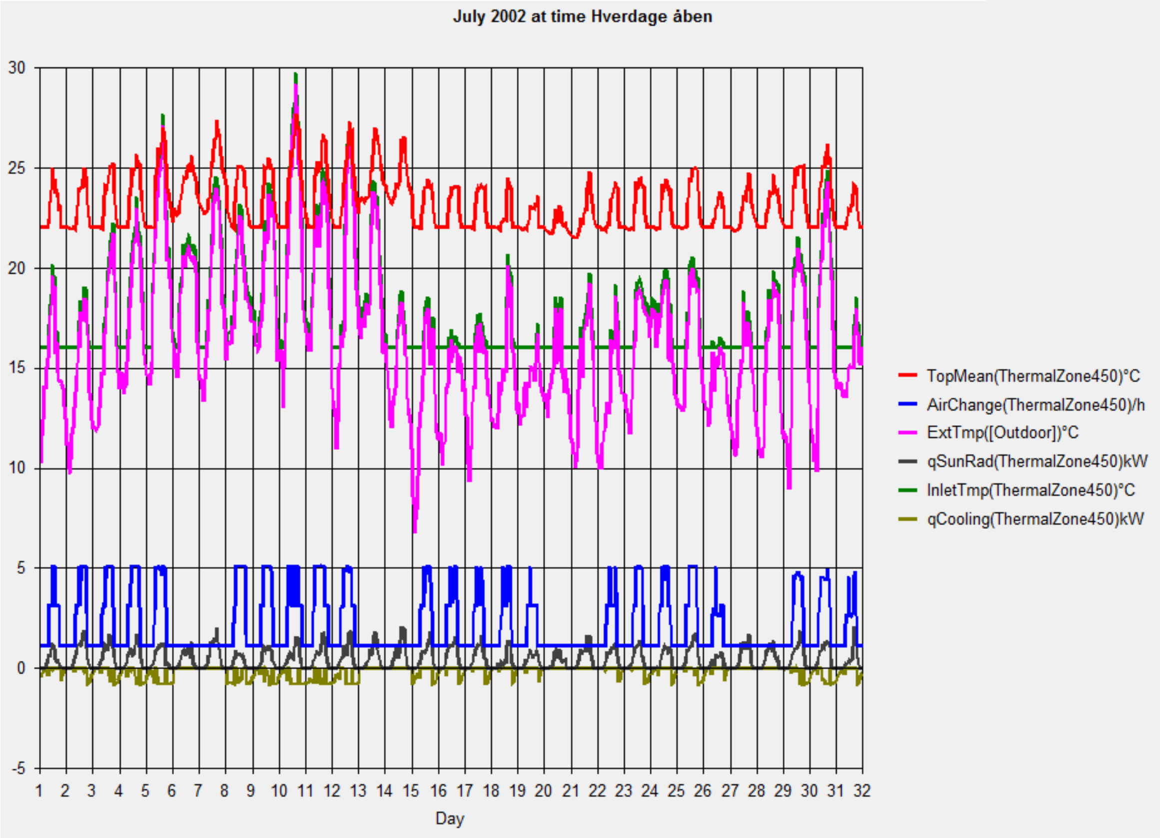


Figure 8 – Scenario 3 – July.

Scenario 3: **Internal sunblind**; ventilation (VAV):): 3h^{-1} summer nights + 3h^{-1} open hours all year + 1h^{-1} always + 2h^{-1} natural vent.; **cooling load: -1 kW (22.6 W/m^2)**.

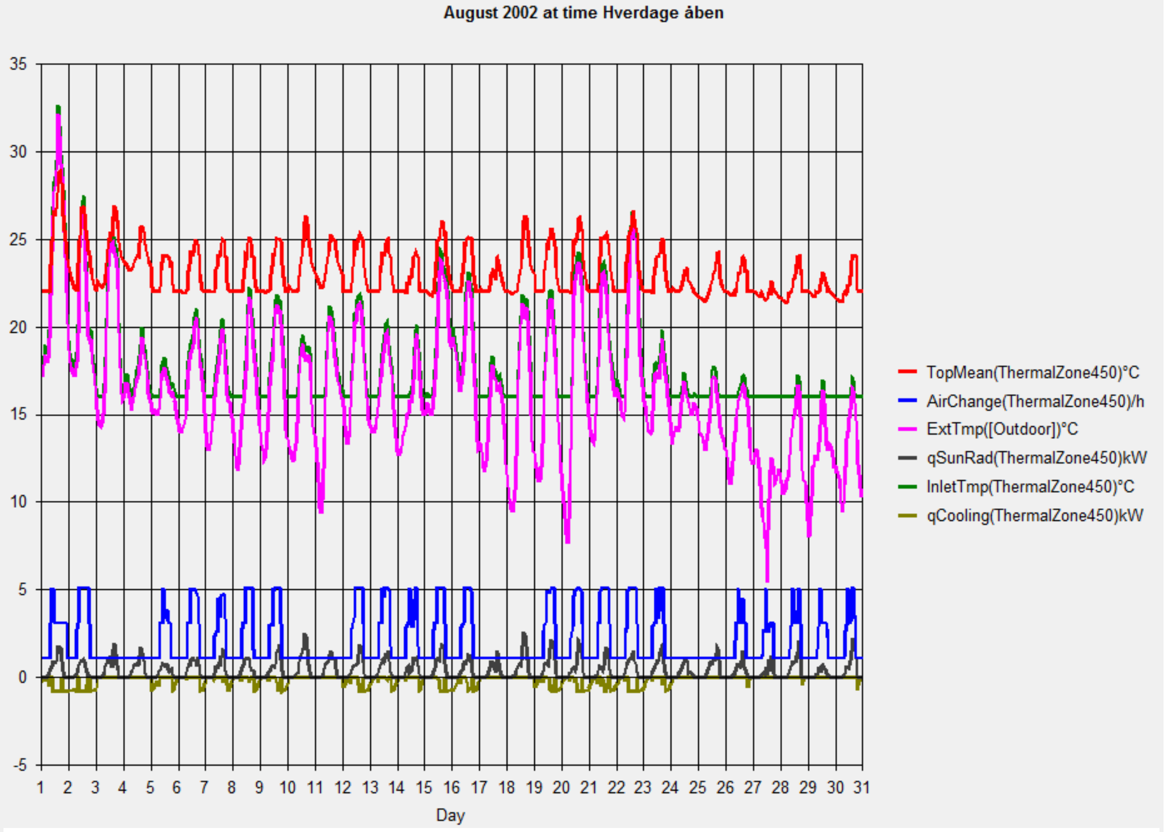


Figure 9 – Scenario 3 – August.

Figure 7, 8 and 9 llustrate scenario 3 with internal sunblinds with a shading factor of 0.8 which causes a much higher external heat load from solar radiation than the scenarios with external sunscreens. To compensate for that it is necessary to double the accesible cooling load compared to scenario 2, when maintaining the same ventilation rates in order to comply with BR10 thermal indoor climate requiements.

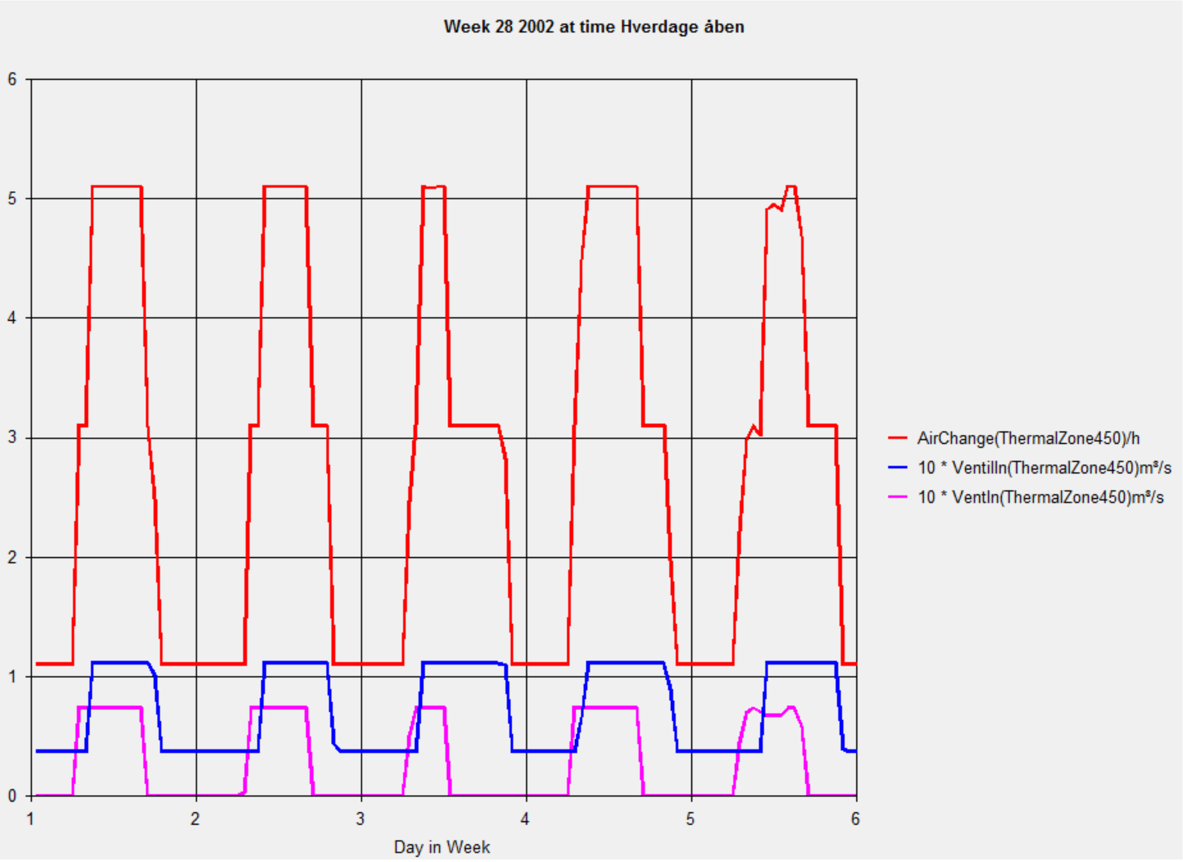


Figure 10 – ventilation example.

Figure 10 shows the mechanical ventilation (Ventilln (blue)) and the natural ventilation (VentIn (purple)) shown seperately .

Conversion example from day 1 peak loads: Ventilln: 1.1 m^3/s → 396 m^3/h → 2.96 h^{-1}, VentIn: 0.08 m^3/s → 288 m^3/h → 2.07 h^{-1}. Combined: 5.1 h^{-1}, which complies well with the dipicted air change graph in figure 14.

Appendix L – Screen prints of the Revit model converted to gbXML format for export to IES<VE>.

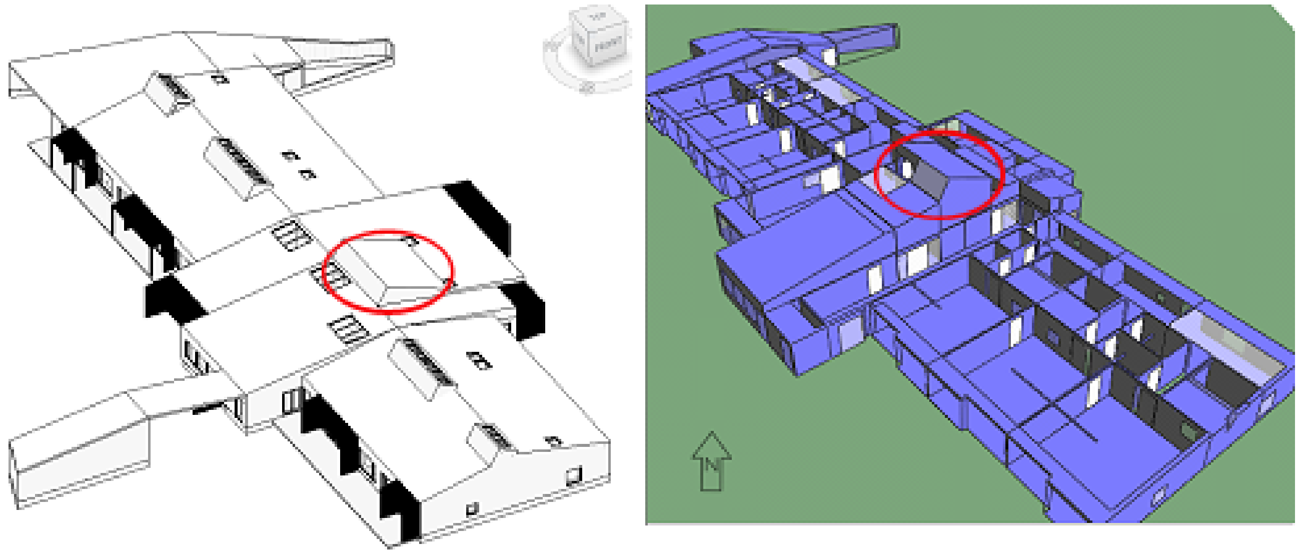
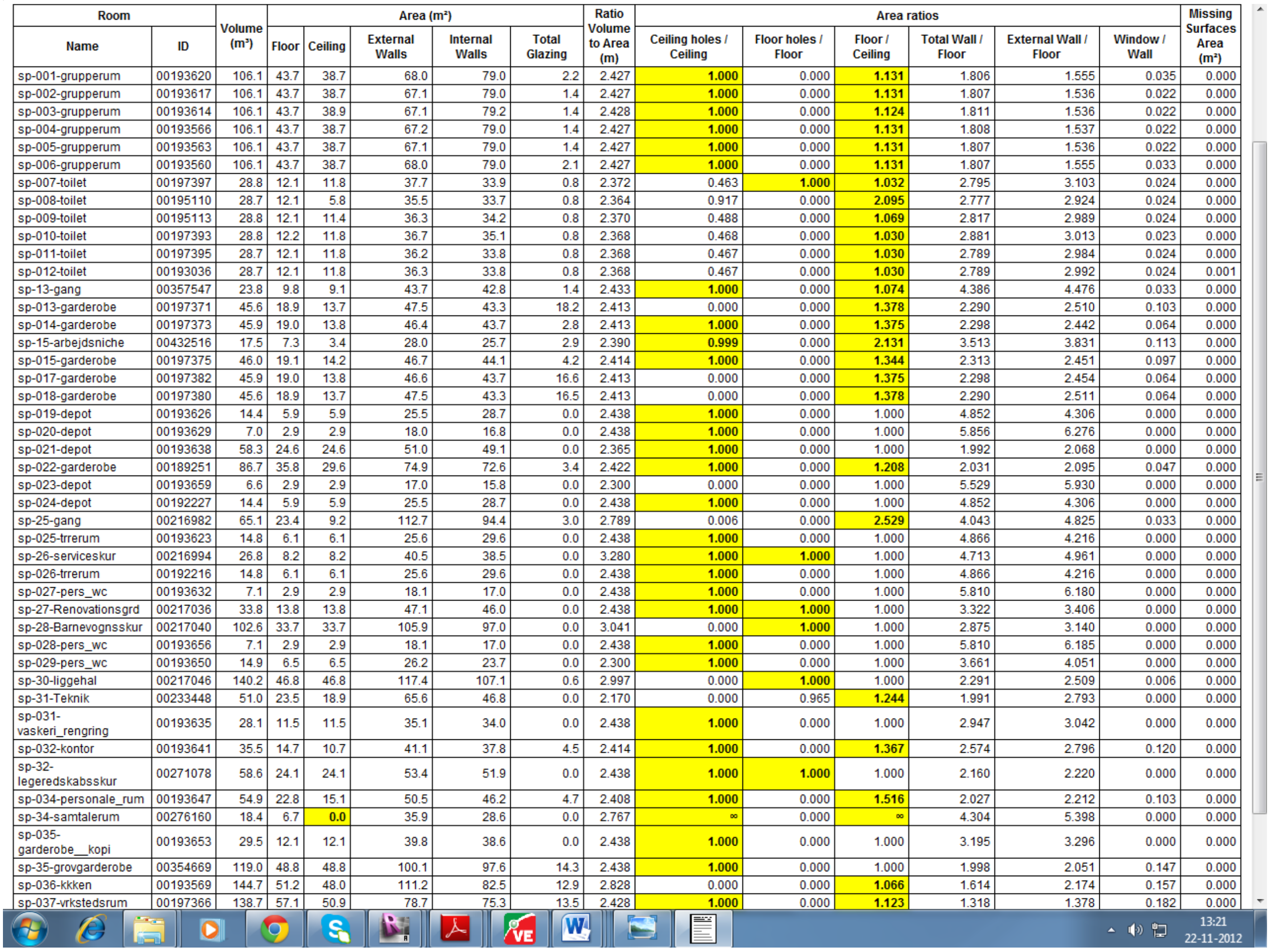


Figure 1 – Left: original Revit model seen in axonometric view. Right gbXML conversion of that exact same model with holes in façade, no roof, partially missing floor, no skylights etc. which is all highlighted in the IES Report below. (The red ellipses encircle the ventilation room which are not present in later models).



Room		Volume (m³)	Area (m²)					Ratio Volume to Area (m)	Area ratios						Missing Surfaces Area (m²)
Name	ID		Floor	Ceiling	External Walls	Internal Walls	Total Glazing		Ceiling holes / Ceiling	Floor holes / Floor	Floor / Ceiling	Total Wall / Floor	External Wall / Floor	Window / Wall	
sp-001-grupperum	00193620	106.1	43.7	38.7	68.0	79.0	2.2	2.427	1.000	0.000	1.131	1.806	1.555	0.035	0.000
sp-002-grupperum	00193617	106.1	43.7	38.7	67.1	79.0	1.4	2.427	1.000	0.000	1.131	1.807	1.536	0.022	0.000
sp-003-grupperum	00193614	106.1	43.7	38.9	67.1	79.2	1.4	2.428	1.000	0.000	1.124	1.811	1.536	0.022	0.000
sp-004-grupperum	00193566	106.1	43.7	38.7	67.2	79.0	1.4	2.427	1.000	0.000	1.131	1.808	1.537	0.022	0.000
sp-005-grupperum	00193563	106.1	43.7	38.7	67.1	79.0	1.4	2.427	1.000	0.000	1.131	1.807	1.536	0.022	0.000
sp-006-grupperum	00193560	106.1	43.7	38.7	68.0	79.0	2.1	2.427	1.000	0.000	1.131	1.807	1.555	0.033	0.000
sp-007-toilet	00197397	28.8	12.1	11.8	37.7	33.9	0.8	2.372	0.463	1.000	1.032	2.795	3.103	0.024	0.000
sp-008-toilet	00195110	28.7	12.1	5.8	35.5	33.7	0.8	2.364	0.917	0.000	2.095	2.777	2.924	0.024	0.000
sp-009-toilet	00195113	28.8	12.1	11.4	36.3	34.2	0.8	2.370	0.488	0.000	1.069	2.817	2.989	0.024	0.000
sp-010-toilet	00197393	28.8	12.2	11.8	36.7	35.1	0.8	2.368	0.468	0.000	1.030	2.881	3.013	0.023	0.000
sp-011-toilet	00197395	28.7	12.1	11.8	36.2	33.8	0.8	2.368	0.467	0.000	1.030	2.789	2.984	0.024	0.000
sp-012-toilet	00193036	28.7	12.1	11.8	36.3	33.8	0.8	2.368	0.467	0.000	1.030	2.789	2.992	0.024	0.001
sp-13-gang	00357547	23.8	9.8	9.1	43.7	42.8	1.4	2.433	1.000	0.000	1.074	4.386	4.476	0.033	0.000
sp-013-garderobe	00197371	45.6	18.9	13.7	47.5	43.3	18.2	2.413	0.000	0.000	1.378	2.290	2.510	0.103	0.000
sp-014-garderobe	00197373	45.9	19.0	13.8	46.4	43.7	2.8	2.413	1.000	0.000	1.375	2.298	2.442	0.064	0.000
sp-15-arbejdsniche	00432516	17.5	7.3	3.4	28.0	25.7	2.9	2.390	0.999	0.000	2.131	3.513	3.831	0.113	0.000
sp-015-garderobe	00197375	46.0	19.1	14.2	46.7	44.1	4.2	2.414	1.000	0.000	1.344	2.313	2.451	0.097	0.000
sp-017-garderobe	00197382	45.9	19.0	13.8	46.6	43.7	16.6	2.413	0.000	0.000	1.375	2.298	2.454	0.064	0.000
sp-018-garderobe	00197380	45.6	18.9	13.7	47.5	43.3	16.5	2.413	0.000	0.000	1.378	2.290	2.511	0.064	0.000
sp-019-depot	00193626	14.4	5.9	5.9	25.5	28.7	0.0	2.438	1.000	0.000	1.000	4.852	4.306	0.000	0.000
sp-020-depot	00193629	7.0	2.9	2.9	18.0	16.8	0.0	2.438	1.000	0.000	1.000	5.856	6.276	0.000	0.000
sp-021-depot	00193638	58.3	24.6	24.6	51.0	49.1	0.0	2.365	1.000	0.000	1.000	1.992	2.068	0.000	0.000
sp-022-garderobe	00189251	86.7	35.8	29.6	74.9	72.6	3.4	2.422	1.000	0.000	1.208	2.031	2.095	0.047	0.000
sp-023-depot	00193659	6.6	2.9	2.9	17.0	15.8	0.0	2.300	0.000	0.000	1.000	5.529	5.930	0.000	0.000
sp-024-depot	00192227	14.4	5.9	5.9	25.5	28.7	0.0	2.438	1.000	0.000	1.000	4.852	4.306	0.000	0.000
sp-25-gang	00216982	65.1	23.4	9.2	112.7	94.4	3.0	2.789	0.006	0.000	2.529	4.043	4.825	0.033	0.000
sp-025-trrerum	00193623	14.8	6.1	6.1	25.6	29.6	0.0	2.438	1.000	0.000	1.000	4.866	4.216	0.000	0.000
sp-26-serviceskur	00216994	26.8	8.2	8.2	40.5	38.5	0.0	3.280	1.000	1.000	1.000	4.713	4.961	0.000	0.000
sp-026-trrerum	00192216	14.8	6.1	6.1	25.6	29.6	0.0	2.438	1.000	0.000	1.000	4.866	4.216	0.000	0.000
sp-027-pers_wc	00193632	7.1	2.9	2.9	18.1	17.0	0.0	2.438	1.000	0.000	1.000	5.810	6.180	0.000	0.000
sp-27-Renovationsgrd	00217036	33.8	13.8	13.8	47.1	46.0	0.0	2.438	1.000	1.000	1.000	3.322	3.406	0.000	0.000
sp-28-Barnevognsskur	00217040	102.6	33.7	33.7	105.9	97.0	0.0	3.041	0.000	1.000	1.000	2.875	3.140	0.000	0.000
sp-028-pers_wc	00193656	7.1	2.9	2.9	18.1	17.0	0.0	2.438	1.000	0.000	1.000	5.810	6.185	0.000	0.000
sp-029-pers_wc	00193650	14.9	6.5	6.5	26.2	23.7	0.0	2.300	1.000	0.000	1.000	3.661	4.051	0.000	0.000
sp-30-liggehal	00217046	140.2	46.8	46.8	117.4	107.1	0.6	2.997	0.000	1.000	1.000	2.291	2.509	0.006	0.000
sp-31-Teknik	00233448	51.0	23.5	18.9	65.6	46.8	0.0	2.170	0.000	0.965	1.244	1.991	2.793	0.000	0.000
sp-031-vaskeri_rengring	00193635	28.1	11.5	11.5	35.1	34.0	0.0	2.438	1.000	0.000	1.000	2.947	3.042	0.000	0.000
sp-032-kontor	00193641	35.5	14.7	10.7	41.1	37.8	4.5	2.414	1.000	0.000	1.367	2.574	2.796	0.120	0.000
sp-32-legeredskabsskur	00271078	58.6	24.1	24.1	53.4	51.9	0.0	2.438	1.000	1.000	1.000	2.160	2.220	0.000	0.000
sp-034-personale_rum	00193647	54.9	22.8	15.1	50.5	46.2	4.7	2.408	1.000	0.000	1.516	2.027	2.212	0.103	0.000
sp-34-samtalerum	00276160	18.4	6.7	0.0	35.9	28.6	0.0	2.767	∞	0.000	∞	4.304	5.398	0.000	0.000
sp-035-garderobe__kopi	00193653	29.5	12.1	12.1	39.8	38.6	0.0	2.438	1.000	0.000	1.000	3.195	3.296	0.000	0.000
sp-35-grovgarderobe	00354669	119.0	48.8	48.8	100.1	97.6	14.3	2.438	1.000	0.000	1.000	1.998	2.051	0.147	0.000
sp-036-kkken	00193569	144.7	51.2	48.0	111.2	82.5	12.9	2.828	0.000	0.000	1.066	1.614	2.174	0.157	0.000
sp-037-vrkstedsrum	00197366	138.7	57.1	50.9	78.7	75.3	13.5	2.428	1.000	0.000	1.123	1.318	1.378	0.182	0.000

Figure2 – EIS Report or the original model made in the conversion process from Revit file to gbXML file. The report highlights where there are holes, unconnected surfaces, unbounded rooms and many other errors.

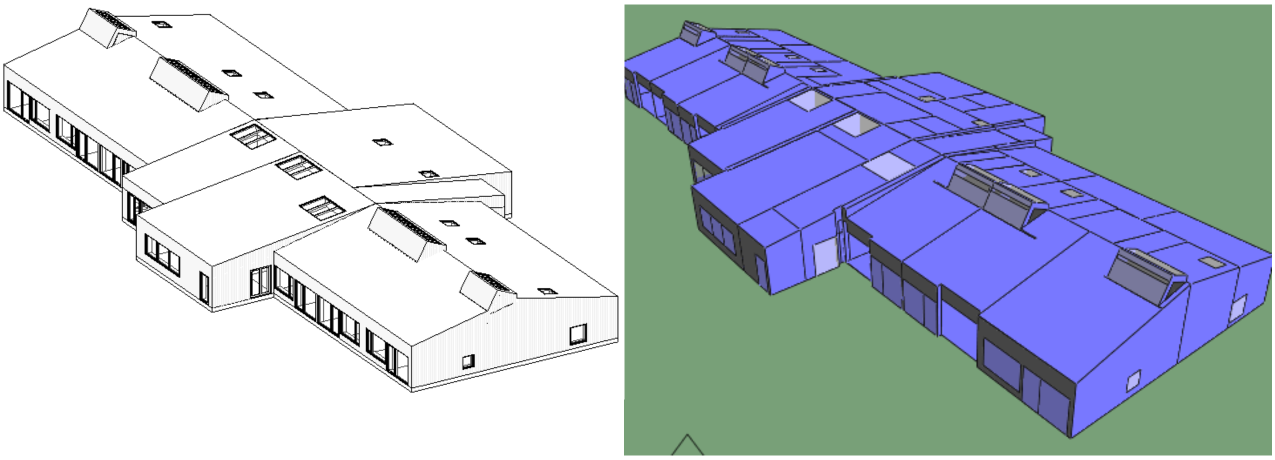
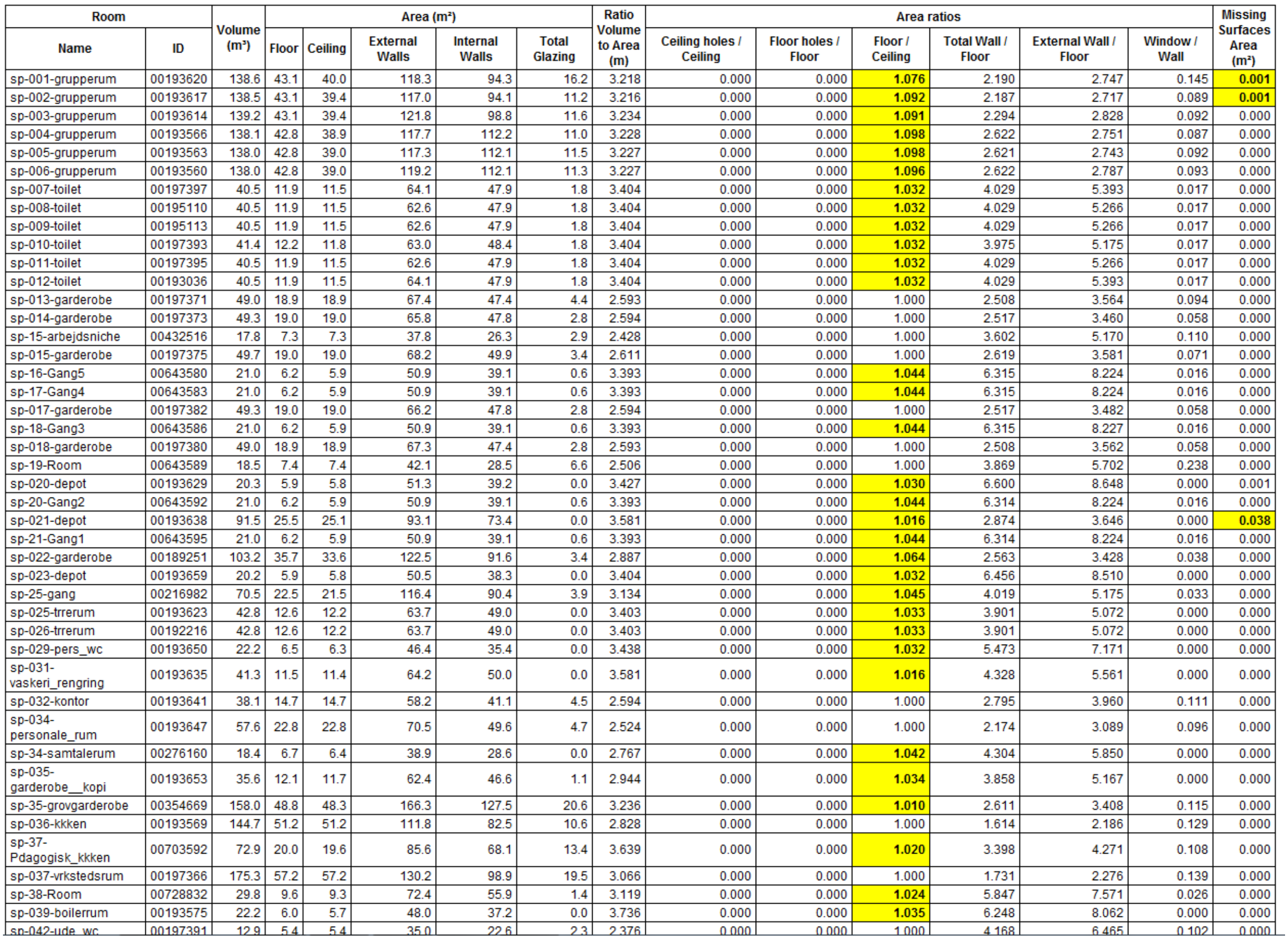


Figure 3 – Left: simplified Revit model with no ventilation room on first floor. Right: the corresponding gbXML file with more accurate room definitions but still loads of unresolved issues with the façade, skylights etc.



Room		Volume (m^3)	Area (m^2)					Ratio Volume to Area (m)	Area ratios						Missing Surfaces Area (m^2)
Name	ID		Floor	Ceiling	External Walls	Internal Walls	Total Glazing		Ceiling holes / Ceiling	Floor holes / Floor	Floor / Ceiling	Total Wall / Floor	External Wall / Floor	Window / Wall	
sp-001-grupperum	00193620	138.6	43.1	40.0	118.3	94.3	16.2	3.218	0.000	0.000	**1.076**	2.190	2.747	0.145	**0.001**
sp-002-grupperum	00193617	138.5	43.1	39.4	117.0	94.1	11.2	3.216	0.000	0.000	**1.092**	2.187	2.717	0.089	**0.001**
sp-003-grupperum	00193614	139.2	43.1	39.4	121.8	98.8	11.6	3.234	0.000	0.000	**1.091**	2.294	2.828	0.092	0.000
sp-004-grupperum	00193566	138.1	42.8	38.9	117.7	112.2	11.0	3.228	0.000	0.000	**1.098**	2.622	2.751	0.087	0.000
sp-005-grupperum	00193563	138.0	42.8	39.0	117.3	112.1	11.5	3.227	0.000	0.000	**1.098**	2.621	2.743	0.092	0.000
sp-006-grupperum	00193560	138.0	42.8	39.0	119.2	112.1	11.3	3.227	0.000	0.000	**1.096**	2.622	2.787	0.093	0.000
sp-007-toilet	00197397	40.5	11.9	11.5	64.1	47.9	1.8	3.404	0.000	0.000	**1.032**	4.029	5.393	0.017	0.000
sp-008-toilet	00195110	40.5	11.9	11.5	62.6	47.9	1.8	3.404	0.000	0.000	**1.032**	4.029	5.266	0.017	0.000
sp-009-toilet	00195113	40.5	11.9	11.5	62.6	47.9	1.8	3.404	0.000	0.000	**1.032**	4.029	5.266	0.017	0.000
sp-010-toilet	00197393	41.4	12.2	11.8	63.0	48.4	1.8	3.404	0.000	0.000	**1.032**	3.975	5.175	0.017	0.000
sp-011-toilet	00197395	40.5	11.9	11.5	62.6	47.9	1.8	3.404	0.000	0.000	**1.032**	4.029	5.266	0.017	0.000
sp-012-toilet	00193036	40.5	11.9	11.5	64.1	47.9	1.8	3.404	0.000	0.000	**1.032**	4.029	5.393	0.017	0.000
sp-013-garderobe	00197371	49.0	18.9	18.9	67.4	47.4	4.4	2.593	0.000	0.000	1.000	2.508	3.564	0.094	0.000
sp-014-garderobe	00197373	49.3	19.0	19.0	65.8	47.8	2.8	2.594	0.000	0.000	1.000	2.517	3.460	0.058	0.000
sp-15-arbejdsniche	00432516	17.8	7.3	7.3	37.8	26.3	2.9	2.428	0.000	0.000	1.000	3.602	5.170	0.110	0.000
sp-015-garderobe	00197375	49.7	19.0	19.0	68.2	49.9	3.4	2.611	0.000	0.000	1.000	2.619	3.581	0.071	0.000
sp-16-Gang5	00643580	21.0	6.2	5.9	50.9	39.1	0.6	3.393	0.000	0.000	**1.044**	6.315	8.224	0.016	0.000
sp-17-Gang4	00643583	21.0	6.2	5.9	50.9	39.1	0.6	3.393	0.000	0.000	**1.044**	6.315	8.224	0.016	0.000
sp-017-garderobe	00197382	49.3	19.0	19.0	66.2	47.8	2.8	2.594	0.000	0.000	1.000	2.517	3.482	0.058	0.000
sp-18-Gang3	00643586	21.0	6.2	5.9	50.9	39.1	0.6	3.393	0.000	0.000	**1.044**	6.315	8.227	0.016	0.000
sp-018-garderobe	00197380	49.0	18.9	18.9	67.3	47.4	2.8	2.593	0.000	0.000	1.000	2.508	3.562	0.058	0.000
sp-19-Room	00643589	18.5	7.4	7.4	42.1	28.5	6.6	2.506	0.000	0.000	1.000	3.869	5.702	0.238	0.000
sp-020-depot	00193629	20.3	5.9	5.8	51.3	39.2	0.0	3.427	0.000	0.000	**1.030**	6.600	8.648	0.000	0.001
sp-20-Gang2	00643592	21.0	6.2	5.9	50.9	39.1	0.6	3.393	0.000	0.000	**1.044**	6.314	8.224	0.016	0.000
sp-021-depot	00193638	91.5	25.5	25.1	93.1	73.4	0.0	3.581	0.000	0.000	**1.016**	2.874	3.646	0.000	**0.038**
sp-21-Gang1	00643595	21.0	6.2	5.9	50.9	39.1	0.6	3.393	0.000	0.000	**1.044**	6.314	8.224	0.016	0.000
sp-022-garderobe	00189251	103.2	35.7	33.6	122.5	91.6	3.4	2.887	0.000	0.000	**1.064**	2.563	3.428	0.038	0.000
sp-023-depot	00193659	20.2	5.9	5.8	50.5	38.3	0.0	3.404	0.000	0.000	**1.032**	6.456	8.510	0.000	0.000
sp-25-gang	00216982	70.5	22.5	21.5	116.4	90.4	3.9	3.134	0.000	0.000	**1.045**	4.019	5.175	0.033	0.000
sp-025-trrerum	00193623	42.8	12.6	12.2	63.7	49.0	0.0	3.403	0.000	0.000	**1.033**	3.901	5.072	0.000	0.000
sp-026-trrerum	00192216	42.8	12.6	12.2	63.7	49.0	0.0	3.403	0.000	0.000	**1.033**	3.901	5.072	0.000	0.000
sp-029-pers_wc	00193650	22.2	6.5	6.3	46.4	35.4	0.0	3.438	0.000	0.000	**1.032**	5.473	7.171	0.000	0.000
sp-031-vaskeri_rengring	00193635	41.3	11.5	11.4	64.2	50.0	0.0	3.581	0.000	0.000	**1.016**	4.328	5.561	0.000	0.000
sp-032-kontor	00193641	38.1	14.7	14.7	58.2	41.1	4.5	2.594	0.000	0.000	1.000	2.795	3.960	0.111	0.000
sp-034-personale_rum	00193647	57.6	22.8	22.8	70.5	49.6	4.7	2.524	0.000	0.000	1.000	2.174	3.089	0.096	0.000
sp-34-samtalerum	00276160	18.4	6.7	6.4	38.9	28.6	0.0	2.767	0.000	0.000	**1.042**	4.304	5.850	0.000	0.000
sp-035-garderobe__kopi	00193653	35.6	12.1	11.7	62.4	46.6	1.1	2.944	0.000	0.000	**1.034**	3.858	5.167	0.000	0.000
sp-35-grovgarderobe	00354669	158.0	48.8	48.3	166.3	127.5	20.6	3.236	0.000	0.000	**1.010**	2.611	3.408	0.115	0.000
sp-036-kkken	00193569	144.7	51.2	51.2	111.8	82.5	10.6	2.828	0.000	0.000	1.000	1.614	2.186	0.129	0.000
sp-37-Pdagogisk_kkken	00703592	72.9	20.0	19.6	85.6	68.1	13.4	3.639	0.000	0.000	**1.020**	3.398	4.271	0.108	0.000
sp-037-vrkstedsrum	00197366	175.3	57.2	57.2	130.2	98.9	19.5	3.066	0.000	0.000	1.000	1.731	2.276	0.139	0.000
sp-38-Room	00728832	29.8	9.6	9.3	72.4	55.9	1.4	3.119	0.000	0.000	**1.024**	5.847	7.571	0.026	0.000
sp-039-boilerrum	00193575	22.2	6.0	5.7	48.0	37.2	0.0	3.736	0.000	0.000	**1.035**	6.248	8.062	0.000	0.000
sp-042-ude_wc	00197391	12.9	5.4	5.4	35.0	22.6	2.3	2.376	0.000	0.000	1.000	4.168	6.465	0.102	0.000

Figure 4 – The associated IES Report depicting clear progress with the gbXML file with much less highlights, but still loads of unresolved problems that will have to be addressed before the model can be exported correct to IES<VE>.

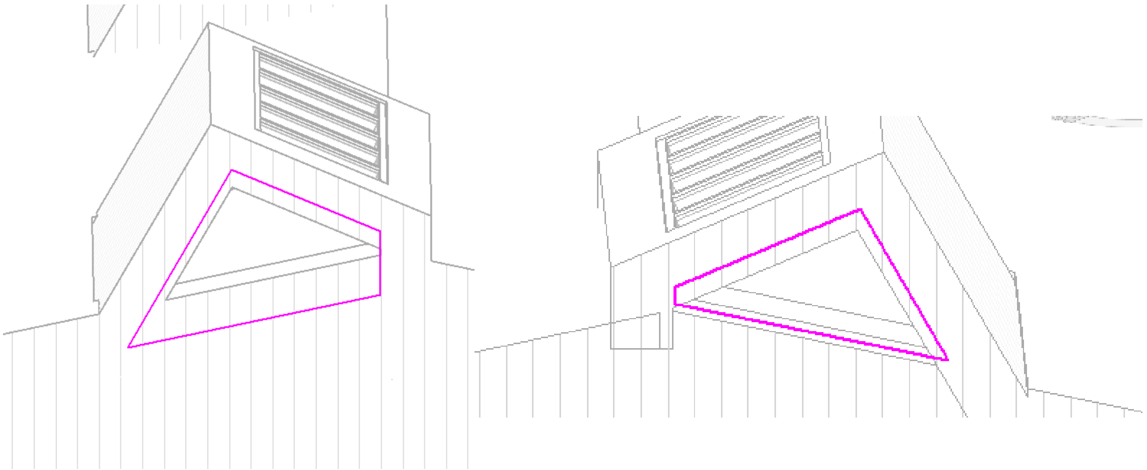


Figure 5 – Illustration of inconsistencies with the skylights causing unclosed holes as can be seen in figure 6 beneath and results in highlighted boxes in the IES Report.

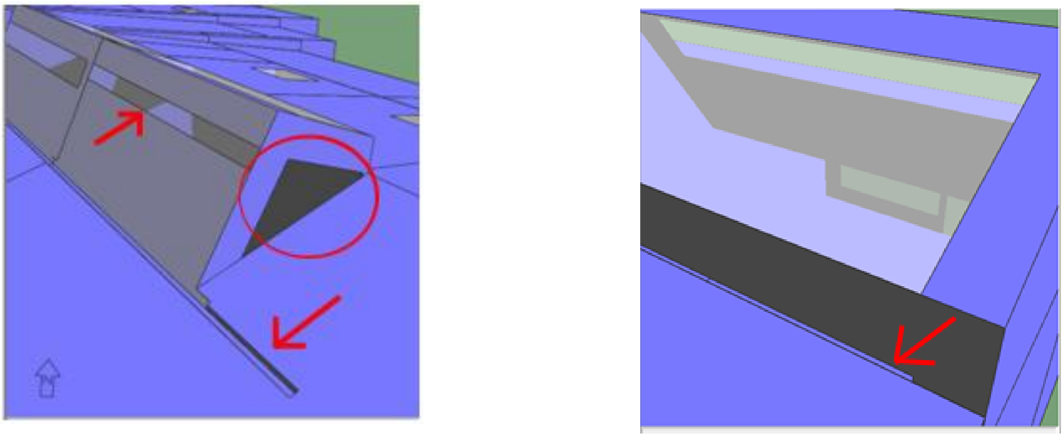


Figure 6 – Skylights construction with all sort of holes in, because they are not connected to the rest of the roof, the sides are designed randomly and inconsistent and a seemingly new window appears on the back of the skylight construction shown on the left by the left arrow.

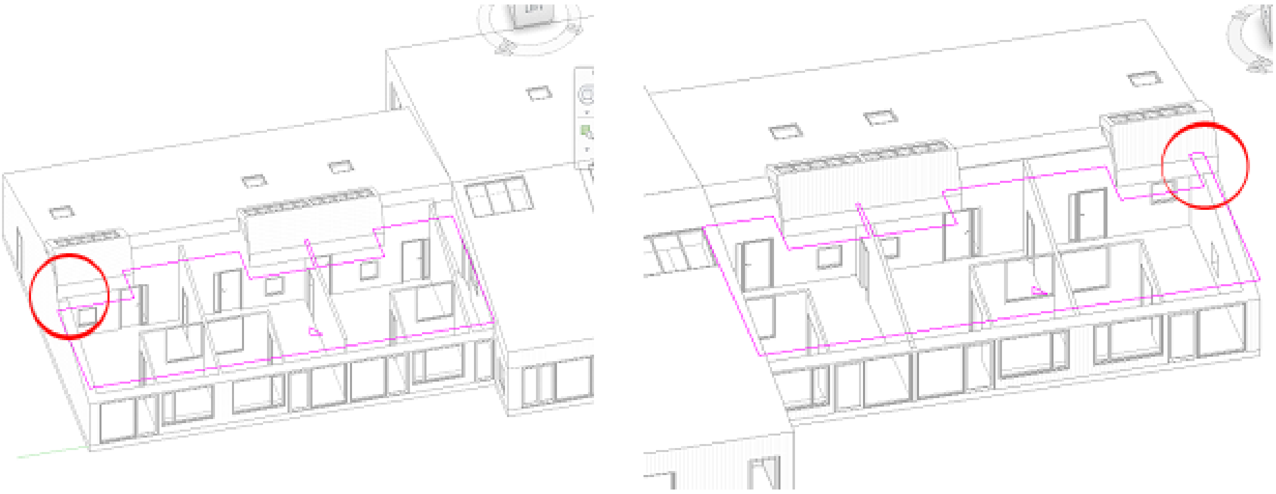


Figure 7 – Another example of inconsistencies with the profile of the roof on each end of the building model causing holes and highlighted boxes in the IES Report.

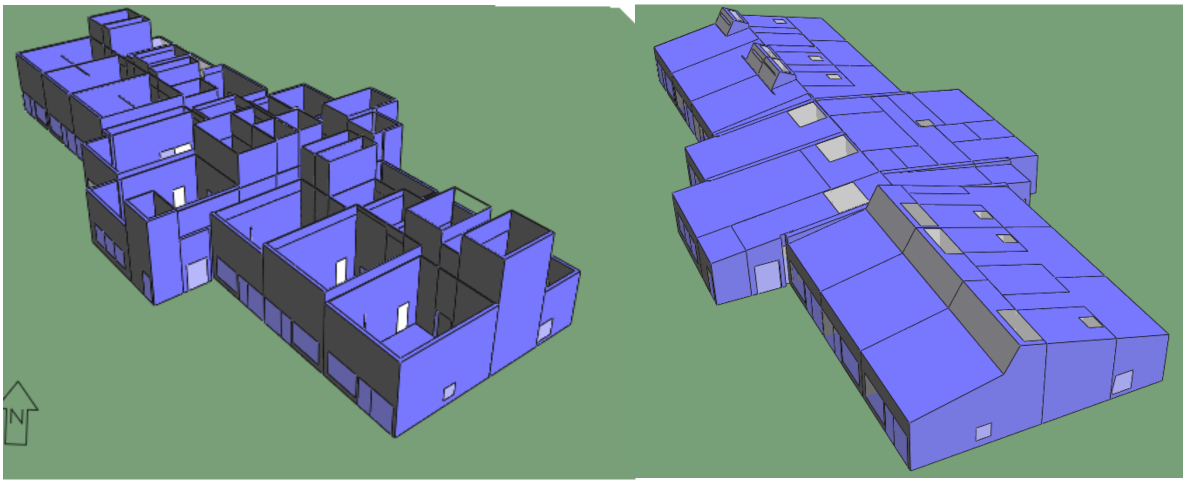


Figure 8 – Left: Example of how the plug-in converts the model into a gbXML file if the default settings are not changed from “Areas” to “Volumes and Areas” in room definition so the converted file displays the rooms without roof bounding elements. Right: same model as on the left but with “Volumes and Areas” activated in room definition. This version of the model was a test of one way of including the skylights without having a separate skylight construction – this version was discarded.

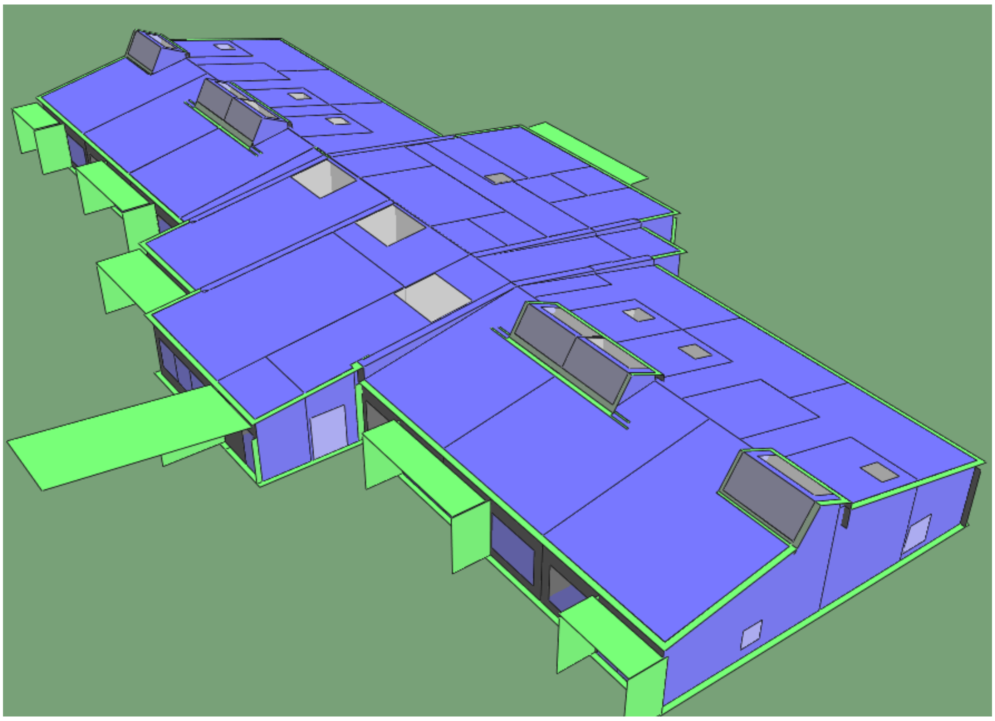
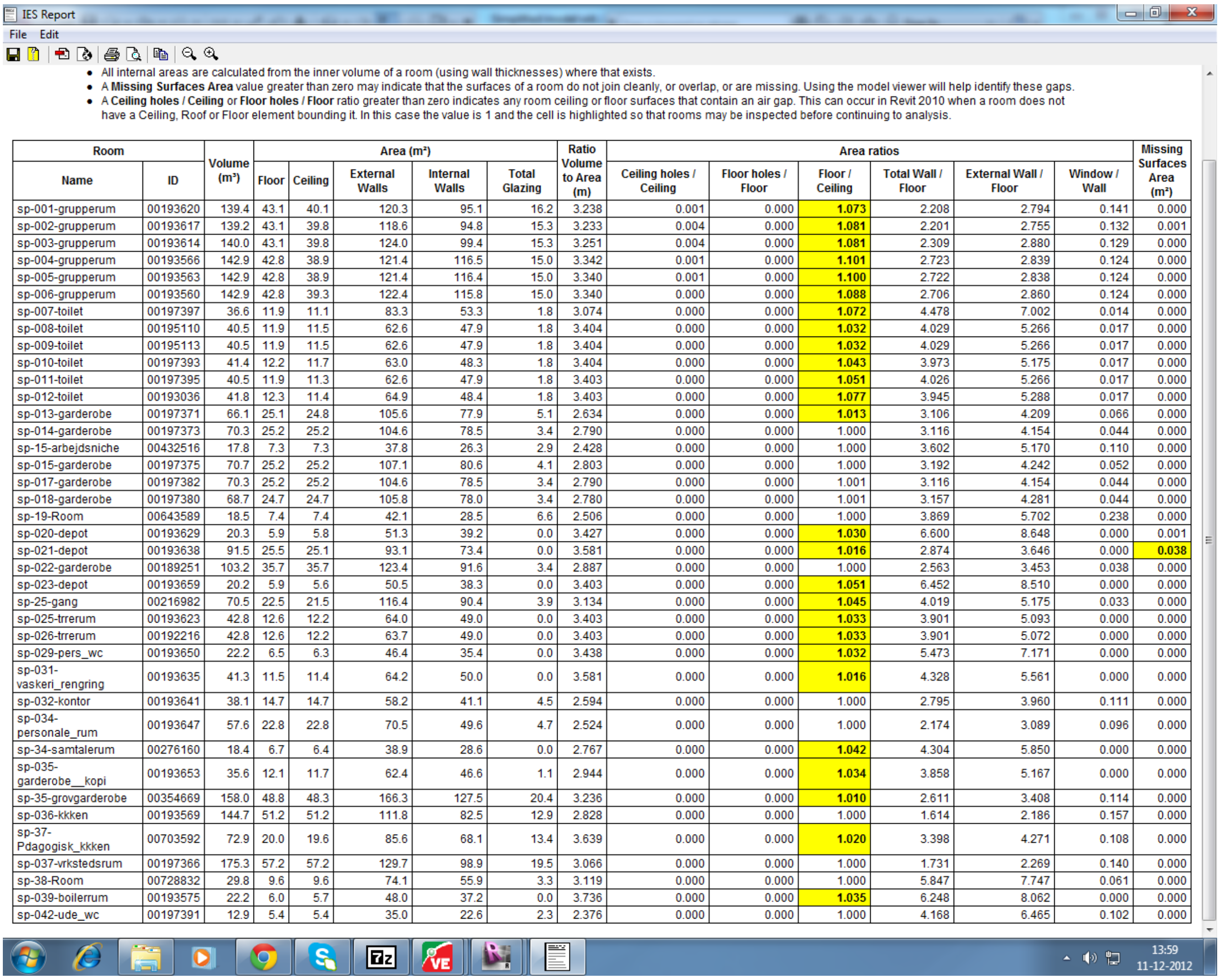


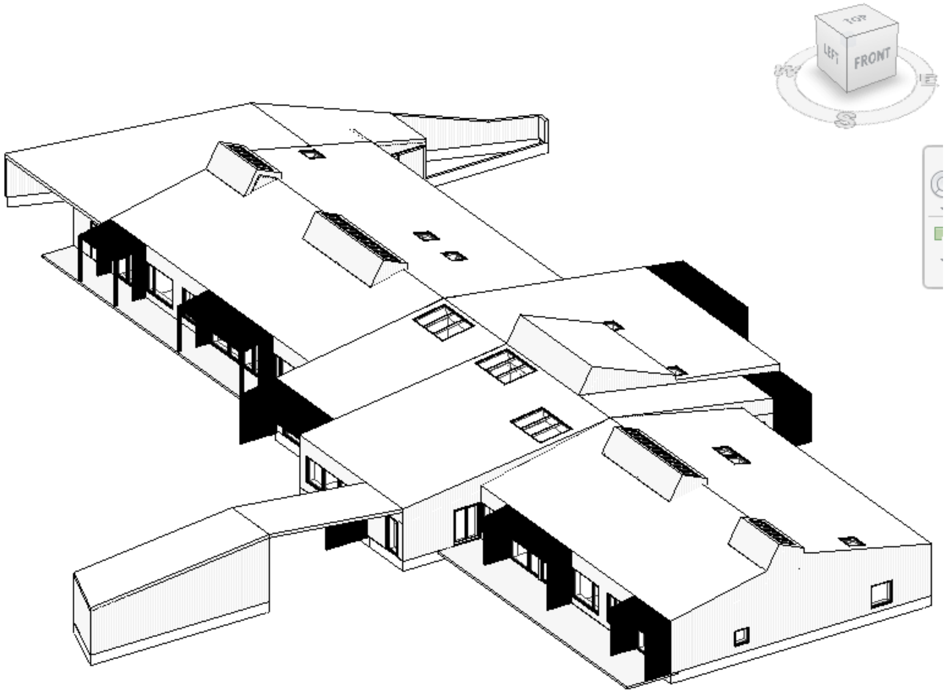
Figure 9 – The final simplified design of the building after a few modifications in IES<VE> . It is very similar to the original design and yet much more simple, which is especially visible on the green shading surfaces such as the pergolas in front of some of the rooms. The pergolas are drawn with the same dimensions as the original ones, but with much fewer surfaces making the file easier to handle and convert (see more details in figures 11 and 12).



- All internal areas are calculated from the inner volume of a room (using wall thicknesses) where that exists.
- A **Missing Surfaces Area** value greater than zero may indicate that the surfaces of a room do not join cleanly, or overlap, or are missing. Using the model viewer will help identify these gaps.
- A **Ceiling holes / Ceiling** or **Floor holes / Floor** ratio greater than zero indicates any room ceiling or floor surfaces that contain an air gap. This can occur in Revit 2010 when a room does not have a Ceiling, Roof or Floor element bounding it. In this case the value is 1 and the cell is highlighted so that rooms may be inspected before continuing to analysis.

Room		Volume (m³)	Area (m²)					Ratio Volume to Area (m)	Area ratios						Missing Surfaces Area (m²)
Name	ID		Floor	Ceiling	External Walls	Internal Walls	Total Glazing		Ceiling holes / Ceiling	Floor holes / Floor	Floor / Ceiling	Total Wall / Floor	External Wall / Floor	Window / Wall	
sp-001-grupperum	00193620	139.4	43.1	40.1	120.3	95.1	16.2	3.238	0.001	0.000	**1.073**	2.208	2.794	0.141	0.000
sp-002-grupperum	00193617	139.2	43.1	39.8	118.6	94.8	15.3	3.233	0.004	0.000	**1.081**	2.201	2.755	0.132	0.001
sp-003-grupperum	00193614	140.0	43.1	39.8	124.0	99.4	15.3	3.251	0.004	0.000	**1.081**	2.309	2.880	0.129	0.000
sp-004-grupperum	00193566	142.9	42.8	38.9	121.4	116.5	15.0	3.342	0.001	0.000	**1.101**	2.723	2.839	0.124	0.000
sp-005-grupperum	00193563	142.9	42.8	38.9	121.4	116.4	15.0	3.340	0.001	0.000	**1.100**	2.722	2.838	0.124	0.000
sp-006-grupperum	00193560	142.9	42.8	39.3	122.4	115.8	15.0	3.340	0.000	0.000	**1.088**	2.706	2.860	0.124	0.000
sp-007-toilet	00197397	36.6	11.9	11.1	83.3	53.3	1.8	3.074	0.000	0.000	**1.072**	4.478	7.002	0.014	0.000
sp-008-toilet	00195110	40.5	11.9	11.5	62.6	47.9	1.8	3.404	0.000	0.000	**1.032**	4.029	5.266	0.017	0.000
sp-009-toilet	00195113	40.5	11.9	11.5	62.6	47.9	1.8	3.404	0.000	0.000	**1.032**	4.029	5.266	0.017	0.000
sp-010-toilet	00197393	41.4	12.2	11.7	63.0	48.3	1.8	3.404	0.000	0.000	**1.043**	3.973	5.175	0.017	0.000
sp-011-toilet	00197395	40.5	11.9	11.3	62.6	47.9	1.8	3.403	0.000	0.000	**1.051**	4.026	5.266	0.017	0.000
sp-012-toilet	00193036	41.8	12.3	11.4	64.9	48.4	1.8	3.403	0.000	0.000	**1.077**	3.945	5.288	0.017	0.000
sp-013-garderobe	00197371	66.1	25.1	24.8	105.6	77.9	5.1	2.634	0.000	0.000	**1.013**	3.106	4.209	0.066	0.000
sp-014-garderobe	00197373	70.3	25.2	25.2	104.6	78.5	3.4	2.790	0.000	0.000	1.000	3.116	4.154	0.044	0.000
sp-15-arbejdsniche	00432516	17.8	7.3	7.3	37.8	26.3	2.9	2.428	0.000	0.000	1.000	3.602	5.170	0.110	0.000
sp-015-garderobe	00197375	70.7	25.2	25.2	107.1	80.6	4.1	2.803	0.000	0.000	1.000	3.192	4.242	0.052	0.000
sp-017-garderobe	00197382	70.3	25.2	25.2	104.6	78.5	3.4	2.790	0.000	0.000	1.001	3.116	4.154	0.044	0.000
sp-018-garderobe	00197380	68.7	24.7	24.7	105.8	78.0	3.4	2.780	0.000	0.000	1.001	3.157	4.281	0.044	0.000
sp-19-Room	00643589	18.5	7.4	7.4	42.1	28.5	6.6	2.506	0.000	0.000	1.000	3.869	5.702	0.238	0.000
sp-020-depot	00193629	20.3	5.9	5.8	51.3	39.2	0.0	3.427	0.000	0.000	**1.030**	6.600	8.648	0.000	0.001
sp-021-depot	00193638	91.5	25.5	25.1	93.1	73.4	0.0	3.581	0.000	0.000	**1.016**	2.874	3.646	0.000	**0.038**
sp-022-garderobe	00189251	103.2	35.7	35.7	123.4	91.6	3.4	2.887	0.000	0.000	1.000	2.563	3.453	0.038	0.000
sp-023-depot	00193659	20.2	5.9	5.6	50.5	38.3	0.0	3.403	0.000	0.000	**1.051**	6.452	8.510	0.000	0.000
sp-25-gang	00216982	70.5	22.5	21.5	116.4	90.4	3.9	3.134	0.000	0.000	**1.045**	4.019	5.175	0.033	0.000
sp-025-trrerum	00193623	42.8	12.6	12.2	64.0	49.0	0.0	3.403	0.000	0.000	**1.033**	3.901	5.093	0.000	0.000
sp-026-trrerum	00192216	42.8	12.6	12.2	63.7	49.0	0.0	3.403	0.000	0.000	**1.033**	3.901	5.072	0.000	0.000
sp-029-pers_wc	00193650	22.2	6.5	6.3	46.4	35.4	0.0	3.438	0.000	0.000	**1.032**	5.473	7.171	0.000	0.000
sp-031-vaskeri_rengring	00193635	41.3	11.5	11.4	64.2	50.0	0.0	3.581	0.000	0.000	**1.016**	4.328	5.561	0.000	0.000
sp-032-kontor	00193641	38.1	14.7	14.7	58.2	41.1	4.5	2.594	0.000	0.000	1.000	2.795	3.960	0.111	0.000
sp-034-personale_rum	00193647	57.6	22.8	22.8	70.5	49.6	4.7	2.524	0.000	0.000	1.000	2.174	3.089	0.096	0.000
sp-34-samtalerum	00276160	18.4	6.7	6.4	38.9	28.6	0.0	2.767	0.000	0.000	**1.042**	4.304	5.850	0.000	0.000
sp-035-garderobe__kopi	00193653	35.6	12.1	11.7	62.4	46.6	1.1	2.944	0.000	0.000	**1.034**	3.858	5.167	0.000	0.000
sp-35-grovgarderobe	00354669	158.0	48.8	48.3	166.3	127.5	20.4	3.236	0.000	0.000	**1.010**	2.611	3.408	0.114	0.000
sp-036-kkken	00193569	144.7	51.2	51.2	111.8	82.5	12.9	2.828	0.000	0.000	1.000	1.614	2.186	0.157	0.000
sp-37-Pdagogisk_kkken	00703592	72.9	20.0	19.6	85.6	68.1	13.4	3.639	0.000	0.000	**1.020**	3.398	4.271	0.108	0.000
sp-037-vrkstedsrum	00197366	175.3	57.2	57.2	129.7	98.9	19.5	3.066	0.000	0.000	1.000	1.731	2.269	0.140	0.000
sp-38-Room	00728832	29.8	9.6	9.6	74.1	55.9	3.3	3.119	0.000	0.000	1.000	5.847	7.747	0.061	0.000
sp-039-boilerrum	00193575	22.2	6.0	5.7	48.0	37.2	0.0	3.736	0.000	0.000	**1.035**	6.248	8.062	0.000	0.000
sp-042-ude_wc	00197391	12.9	5.4	5.4	35.0	22.6	2.3	2.376	0.000	0.000	1.000	4.168	6.465	0.102	0.000

Figure 10 – The corresponding IES Report with only highlights in the “Floor/Ceiling” area ratio indication, which is of no importance because the slanted ceiling is naturally larger than the flat floor. Besides this there is only one highlight at “Missing Surface Area” at a storage room where the analysis will not be focused.



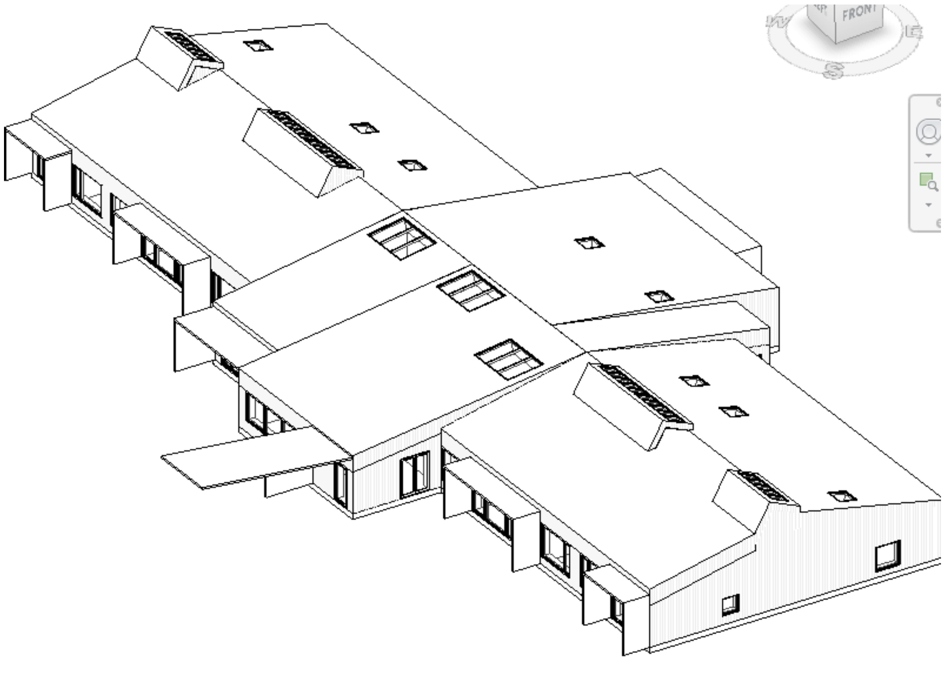


Figure 11 – Top: the original Revit model provided by Rubow Architects. Bottom: The finished simplified model used for further analysis in Solibri and IES<VE>. The small pergola on the back side of the building in front of the main entrance is not drawn in the simplified version, because it has not effect when the main entrance does not contain glass.

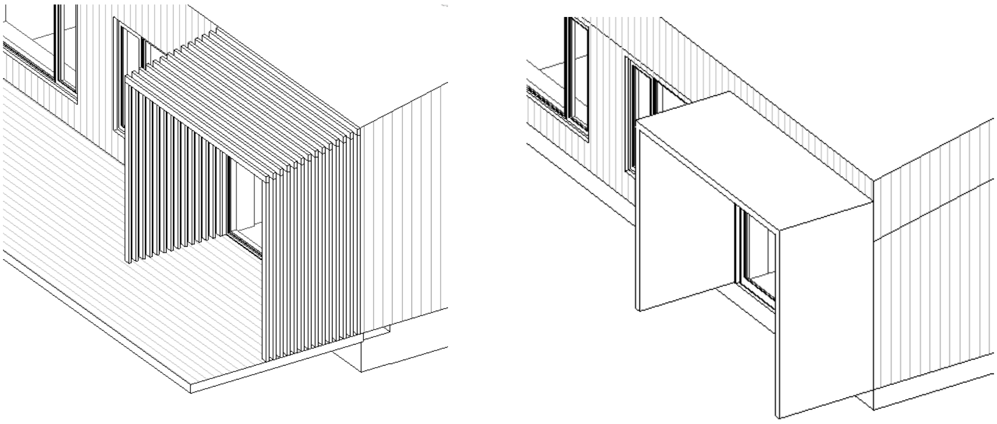
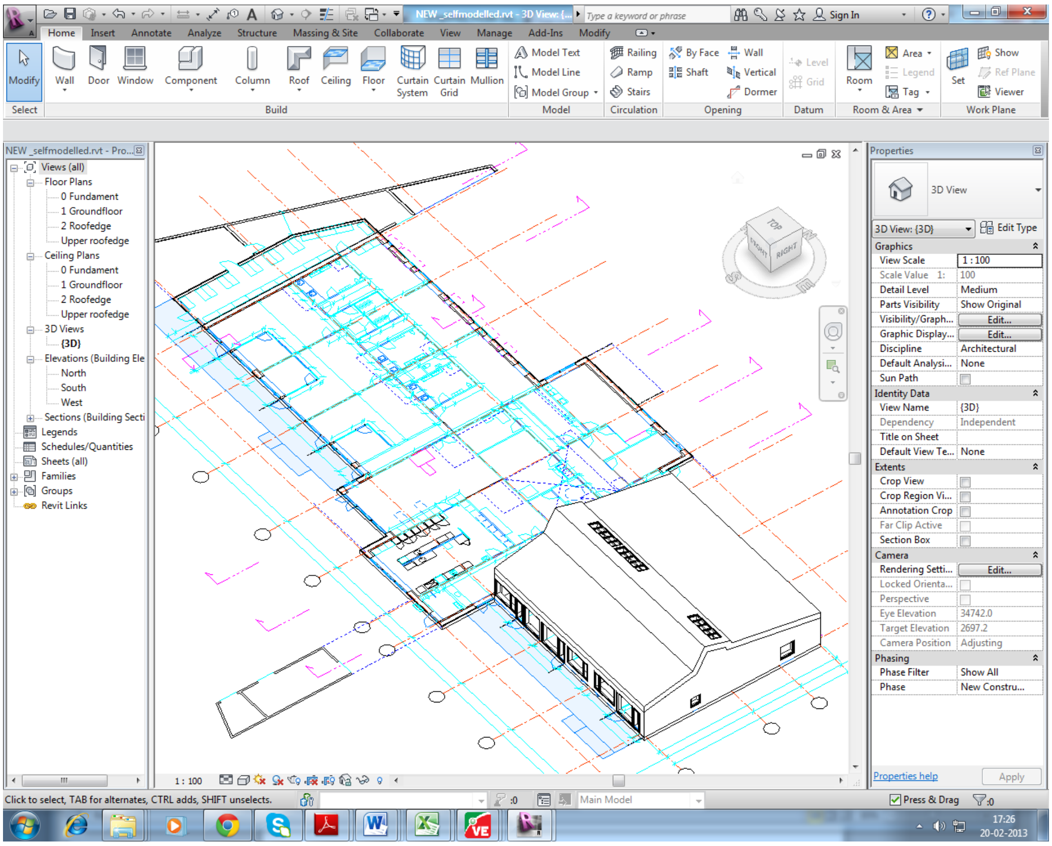


Figure 12 – Left: The original design of the pergola consisting of individual wood columns with small spaces in between. Right: The simplified design of the pergolas as three surfaces. The design to the right is the only one that is convertible to gbXML format, the other one has too many surfaces and prolong the conversion and calculation considerably for no reason.



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Sun Path	☐
Identity Data	
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Title on Sheet	
Default View Te...	None
Extents	
Crop View	☐
Crop Region Vi...	☐
Annotation Crop	☐
Far Clip Active	☐
Section Box	☐
Camera	
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Locked Orienta...	☐
Perspective	☐
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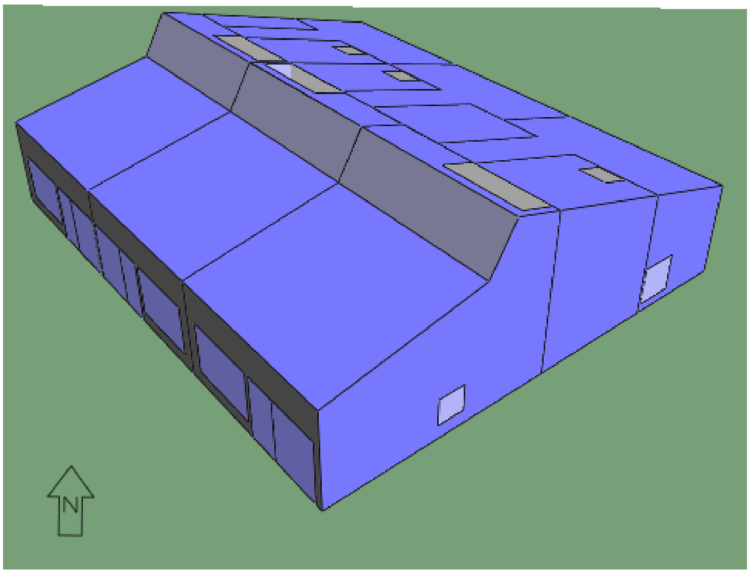
Target Elevation	2697.2
Camera Position	Adjusting
Phasing	
Phase Filter	Show All
Phase	New Constru...

Click to select, TAB for alternates, CTRL adds, SHIFT unselects.

Figure 13 – Screen print of the simple redrawn model in Revit interface. Only 1/3 of the building is modeled as test on top of the imported AutoCAD drawing.



Room		Volume (m³)	Area (m²)					Ratio Volume to Area (m)	Area ratios						Missing Surfaces Area (m²)
Name	ID		Floor	Ceiling	External Walls	Internal Walls	Total Glazing		Ceiling holes / Ceiling	Floor holes / Floor	Floor / Ceiling	Total Wall / Floor	External Wall / Floor	Window / Wall	
sp-001-grupperum	00193620	161.1	43.1	36.6	131.4	109.1	16.0	3.742	0.000	0.000	**1.176**	2.533	3.051	0.115	0.000
sp-002-grupperum	00193617	161.1	43.1	36.6	129.5	109.1	15.1	3.742	0.000	0.000	**1.176**	2.533	3.009	0.108	0.000
sp-003-grupperum	00193614	158.3	42.3	36.0	130.3	108.1	15.2	3.742	0.000	0.000	**1.176**	2.555	3.080	0.109	0.000
sp-007-toilet	00197397	50.4	11.8	11.6	72.5	59.9	1.8	4.278	0.000	0.000	**1.017**	5.089	6.159	0.014	0.000
sp-008-toilet	00195110	50.4	11.8	11.6	70.8	59.9	1.8	4.278	0.000	0.000	**1.017**	5.089	6.015	0.014	0.000
sp-009-toilet	00195113	50.4	11.8	11.6	70.8	59.9	1.8	4.278	0.000	0.000	**1.017**	5.089	6.015	0.014	0.000
sp-013-garderobe	00197371	85.5	24.7	24.7	116.8	97.3	5.0	3.463	0.000	0.000	1.000	3.940	4.733	0.052	0.000
sp-014-garderobe	00197373	85.8	24.8	24.8	115.5	97.8	3.3	3.463	0.000	0.000	1.000	3.946	4.662	0.035	0.000
sp-015-garderobe	00197375	84.5	24.4	24.4	116.1	96.6	3.3	3.467	0.000	0.000	1.000	3.964	4.762	0.035	0.000
sp-020-depot	00193629	23.0	5.4	5.3	57.8	46.9	0.0	4.278	0.000	0.000	**1.017**	8.720	10.740	0.000	0.000
sp-025-trrerum	00193623	52.4	12.3	12.0	71.9	60.9	0.0	4.278	0.000	0.000	**1.017**	4.971	5.872	0.000	0.000

Figure 14 – The same redrawn model as in figure 13 of only the southwestern 1/3 of the building with three common rooms and related facilities. The corresponding IES Report shows only highlights in the "Floor/Ceiling" ratio section so it is good.

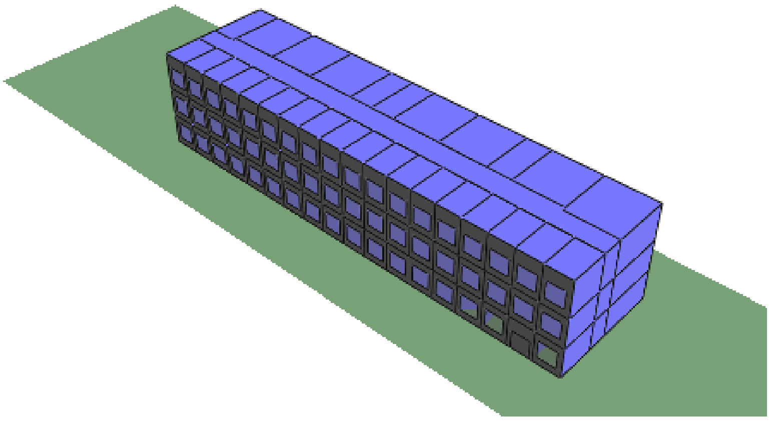


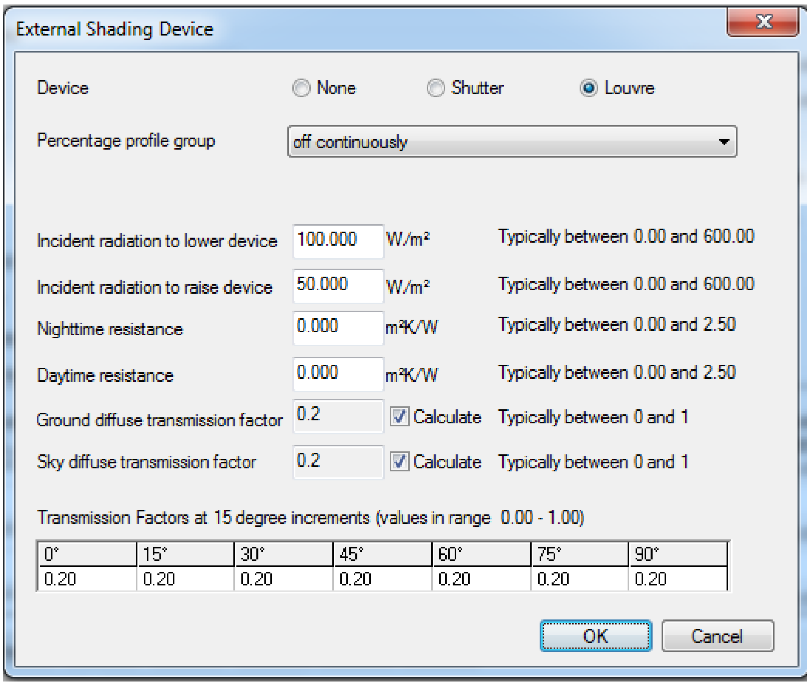
Figure 15 – Simple DTU Building 118 model created in Revit according the IES guidelines and steps described in section 6.1.2 in the report. Just like the simplified mode in figure 13 and 14, there are no transfer problems when it is a strict geometry without any odd surfaces or connections.

Appendix M – Inputs and Results from IES<VE>

Content

Shading devices

All facade windows have exterior shading devices. (Skylights have no shading device, but a lower g-value).



Device ○ None ○ Shutter ● Louvre

Percentage profile group: off continuously

Incident radiation to lower device: 100.000 W/m² Typically between 0.00 and 600.00

Incident radiation to raise device: 50.000 W/m² Typically between 0.00 and 600.00

Nighttime resistance: 0.000 m²K/W Typically between 0.00 and 2.50

Daytime resistance: 0.000 m²K/W Typically between 0.00 and 2.50

Ground diffuse transmission factor: 0.2 ☑ Calculate Typically between 0 and 1

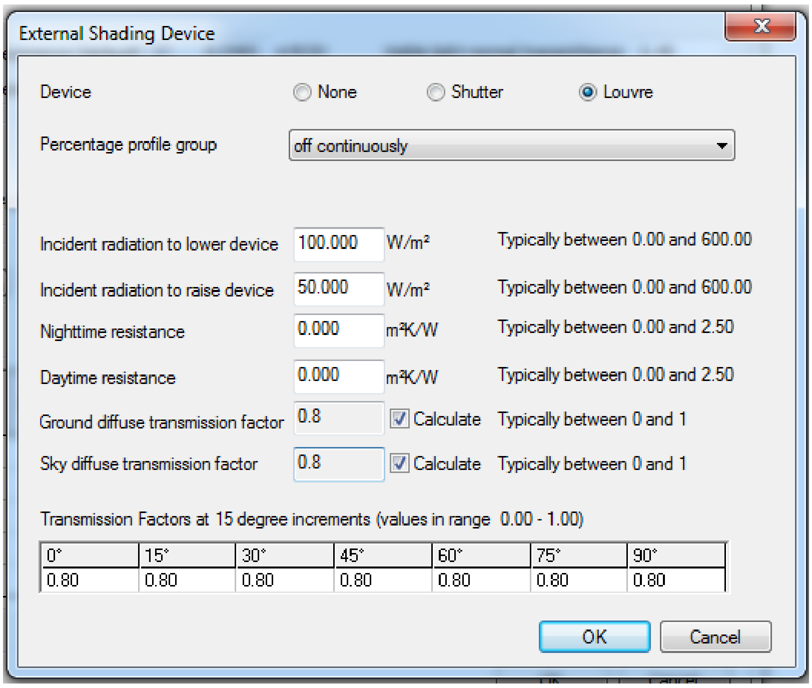
Sky diffuse transmission factor: 0.2 ☑ Calculate Typically between 0 and 1

Transmission Factors at 15 degree increments (values in range 0.00 - 1.00)

0°	15°	30°	45°	60°	75°	90°
0.20	0.20	0.20	0.20	0.20	0.20	0.20

Figure 1 – External shading on the facade windows.

Glass doors hav internal shading devices:



Device ○ None ○ Shutter ● Louvre

Percentage profile group: off continuously

Incident radiation to lower device 100.000 W/m² Typically between 0.00 and 600.00

Incident radiation to raise device 50.000 W/m² Typically between 0.00 and 600.00

Nighttime resistance 0.000 m²K/W Typically between 0.00 and 2.50

Daytime resistance 0.000 m²K/W Typically between 0.00 and 2.50

Ground diffuse transmission factor 0.8 ☑ Calculate Typically between 0 and 1

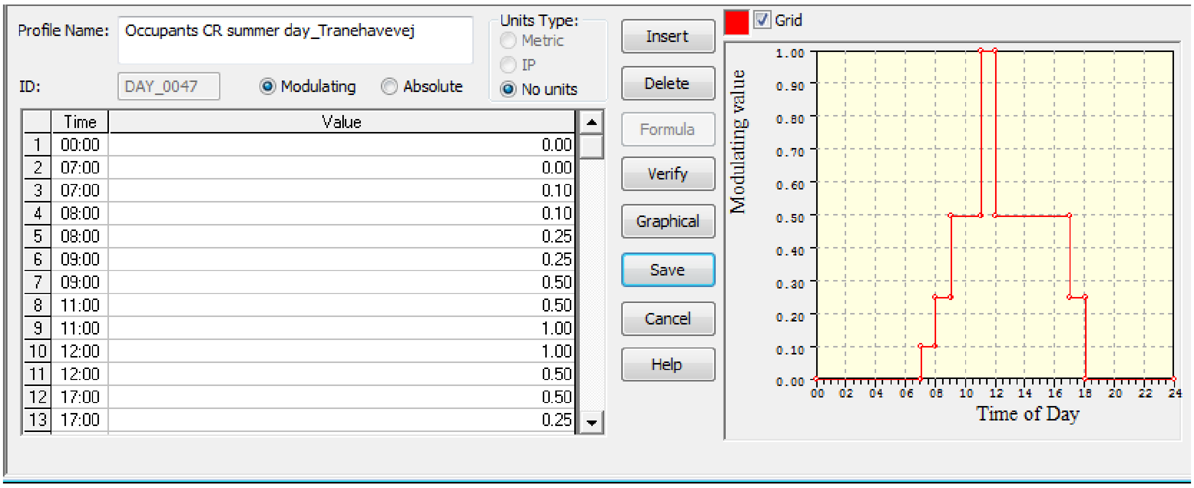
Sky diffuse transmission factor 0.8 ☑ Calculate Typically between 0 and 1

Transmission Factors at 15 degree increments (values in range 0.00 - 1.00)

0°	15°	30°	45°	60°	75°	90°
0.80	0.80	0.80	0.80	0.80	0.80	0.80

Figure 2 – Internal shading on glass doors.

Occupant loads



Profile Name: Occupants CR summer day_Tranehavevej

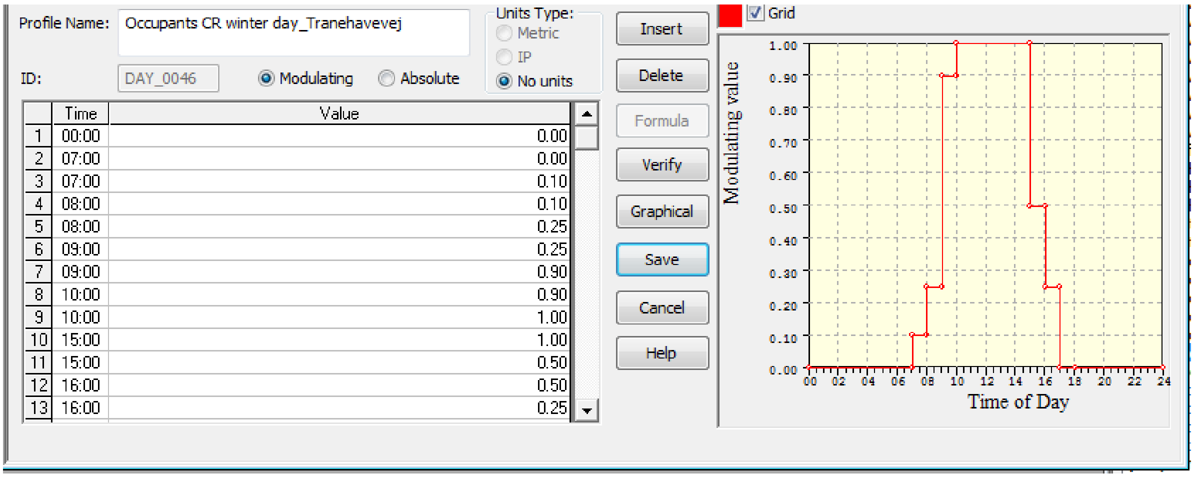
ID: DAY_0047

● Modulating ○ Absolute

Units Type: ○ Metric ○ IP ● No units

	Time	Value
1	00:00	0.00
2	07:00	0.00
3	07:00	0.10
4	08:00	0.10
5	08:00	0.25
6	09:00	0.25
7	09:00	0.50
8	11:00	0.50
9	11:00	1.00
10	12:00	1.00
11	12:00	0.50
12	17:00	0.50
13	17:00	0.25

Figure 3 - Occupant load common rooms summer (mon.-fri. from May to Aug.)



Profile Name: Occupants CR winter day_Tranehavevej

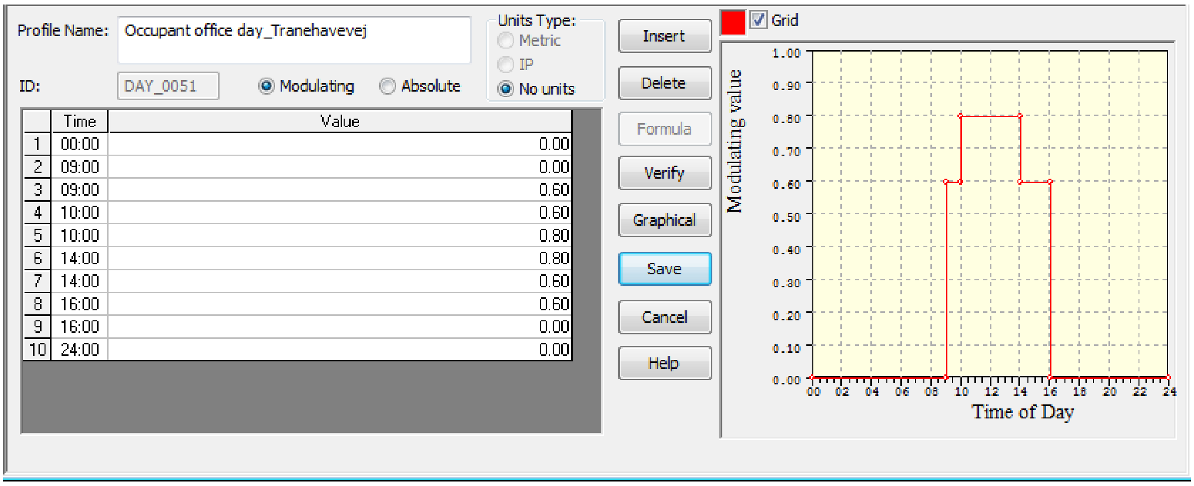
ID: DAY_0046

● Modulating ○ Absolute

Units Type: ○ Metric ○ IP ● No units

	Time	Value
1	00:00	0.00
2	07:00	0.00
3	07:00	0.10
4	08:00	0.10
5	08:00	0.25
6	09:00	0.25
7	09:00	0.90
8	10:00	0.90
9	10:00	1.00
10	15:00	1.00
11	15:00	0.50
12	16:00	0.50
13	16:00	0.25

Figure 4 - Occupant load common rooms winter (mon. –fri.) from Sep. to Apr.).



Profile Name: Occupant office day_Tranehavevej

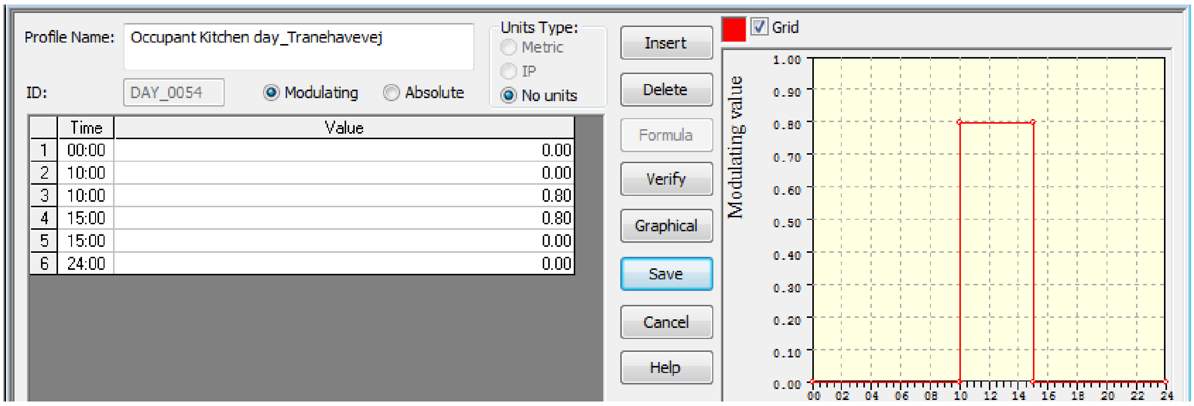
ID: DAY_0051

● Modulating ○ Absolute

Units Type: ○ Metric ○ IP ● No units

	Time	Value
1	00:00	0.00
2	09:00	0.00
3	09:00	0.60
4	10:00	0.60
5	10:00	0.80
6	14:00	0.80
7	14:00	0.60
8	16:00	0.60
9	16:00	0.00
10	24:00	0.00

Figure 5 - Occupant load office week days all year.



Profile Name: Occupant Kitchen day_Tranehavevej

ID: DAY_0054

● Modulating ○ Absolute

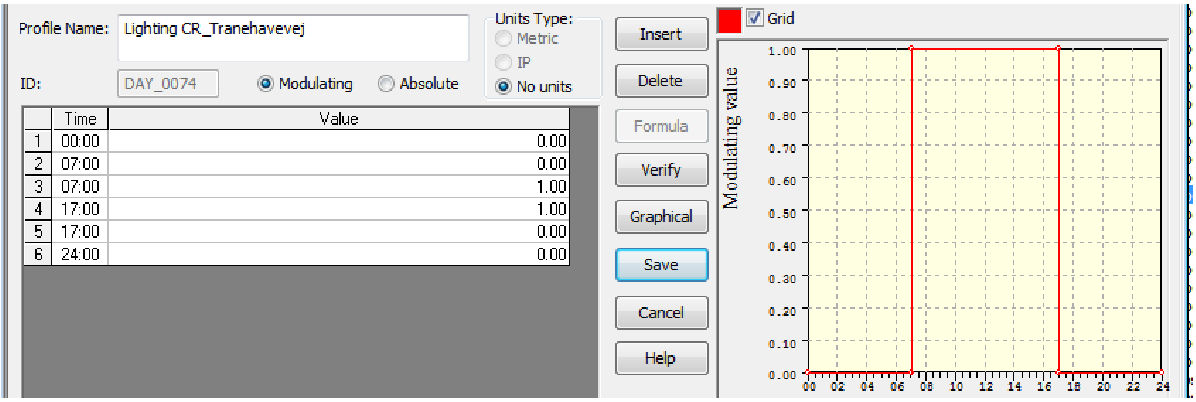
Units Type: ○ Metric ○ IP ● No units

☑ Grid

	Time	Value
1	00:00	0.00
2	10:00	0.00
3	10:00	0.80
4	15:00	0.80
5	15:00	0.00
6	24:00	0.00

Figure 6 - Occupant load kitchen weekdays all year.

Lighting



Profile Name: Lighting CR_Tranehavevej

ID: DAY_0074

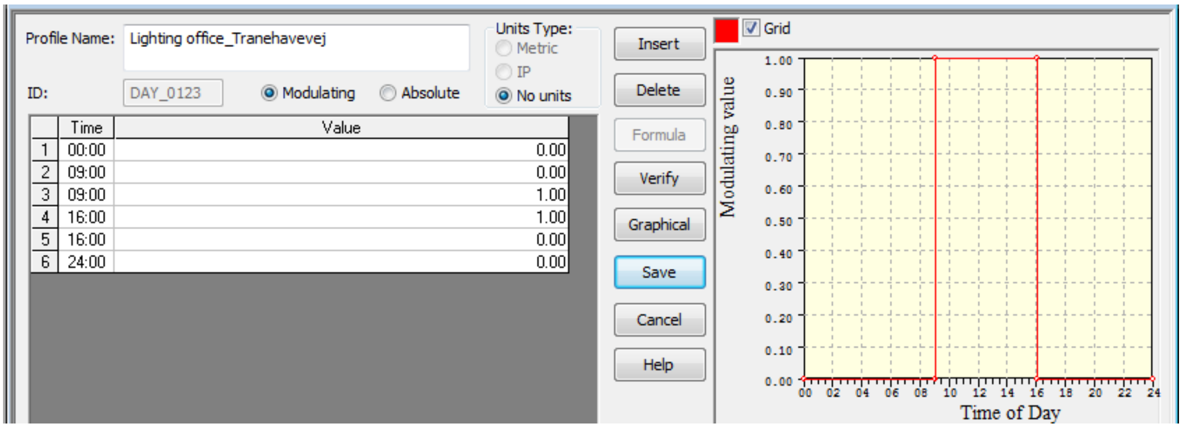
● Modulating ○ Absolute

Units Type: ○ Metric ○ IP ● No units

☑ Grid

	Time	Value
1	00:00	0.00
2	07:00	0.00
3	07:00	1.00
4	17:00	1.00
5	17:00	0.00
6	24:00	0.00

Figure 7 - Lightin common room.



Profile Name: Lighting office_Tranehavevej

ID: DAY_0123

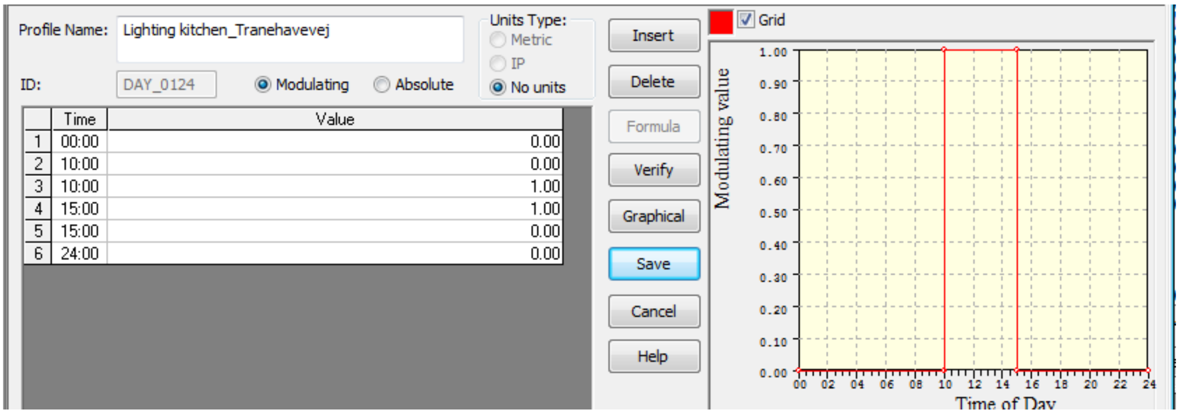
● Modulating ○ Absolute

Units Type: ○ Metric ○ IP ● No units

☑ Grid

	Time	Value
1	00:00	0.00
2	09:00	0.00
3	09:00	1.00
4	16:00	1.00
5	16:00	0.00
6	24:00	0.00

Figure 8 - Lighting office.



Profile Name: Lighting kitchen_Tranehavevej

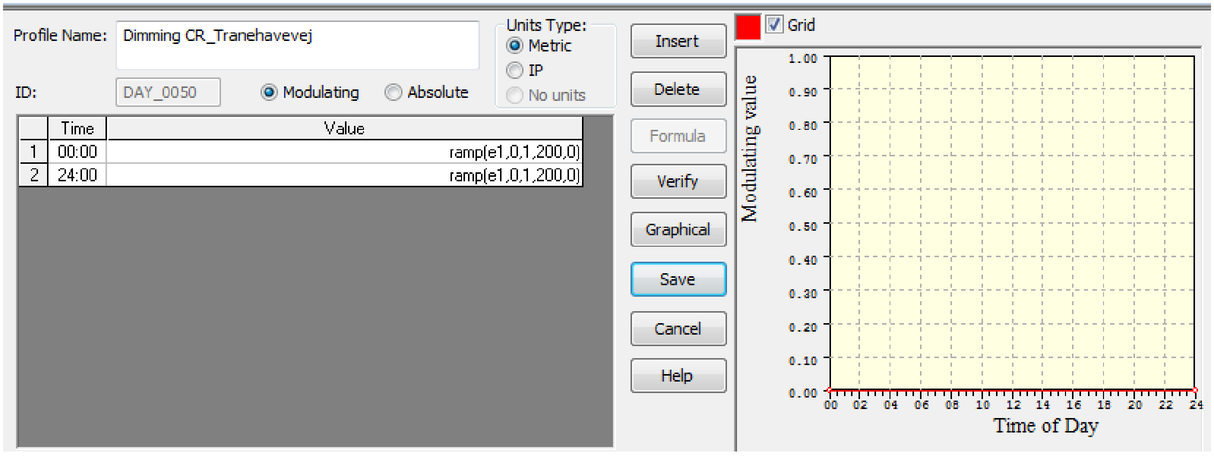
ID: DAY_0124 ● Modulating ○ Absolute

Units Type: ○ Metric ○ IP ● No units

	Time	Value
1	00:00	0.00
2	10:00	0.00
3	10:00	1.00
4	15:00	1.00
5	15:00	0.00
6	24:00	0.00

Figure 9 - Lighting kitchen.

Dimming profiles



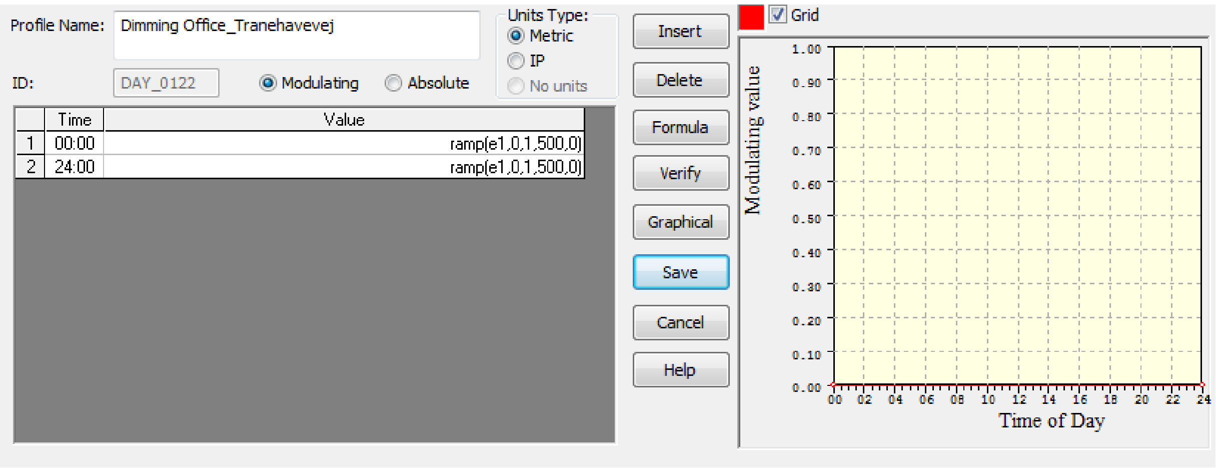
Profile Name: Dimming CR_Tranehavevej

ID: DAY_0050 ● Modulating ○ Absolute

Units Type: ● Metric ○ IP ○ No units

	Time	Value
1	00:00	ramp(e1,0,1,200,0)
2	24:00	ramp(e1,0,1,200,0)

Figure 10 - Dimmin profile common rooms.



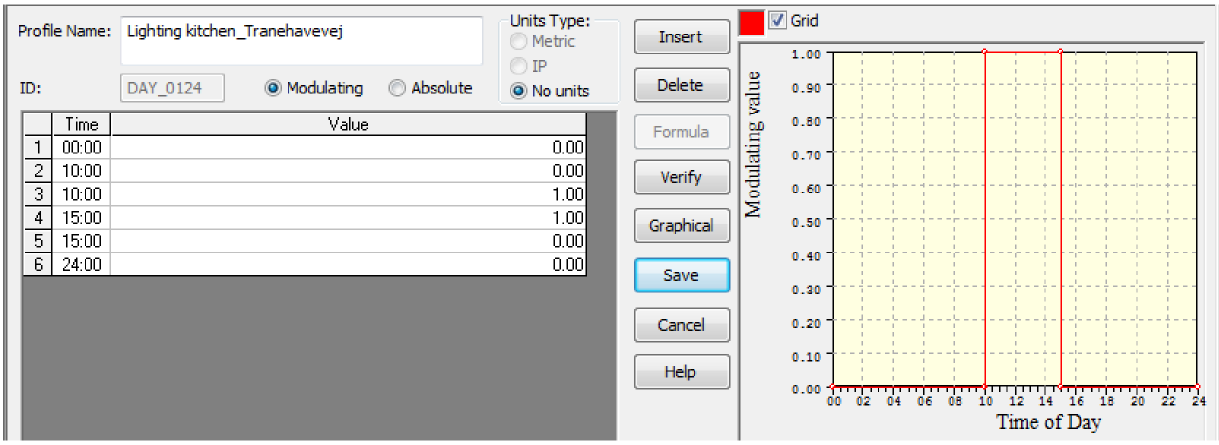
Profile Name: Dimming Office_Tranehavevej

ID: DAY_0122 ● Modulating ○ Absolute

Units Type: ● Metric ○ IP ○ No units

	Time	Value
1	00:00	ramp(e1,0,1,500,0)
2	24:00	ramp(e1,0,1,500,0)

Figure 11 - Dimmin profile office.



Profile Name: Lighting kitchen_Tranehavevej

ID: DAY_0124 ● Modulating ○ Absolute

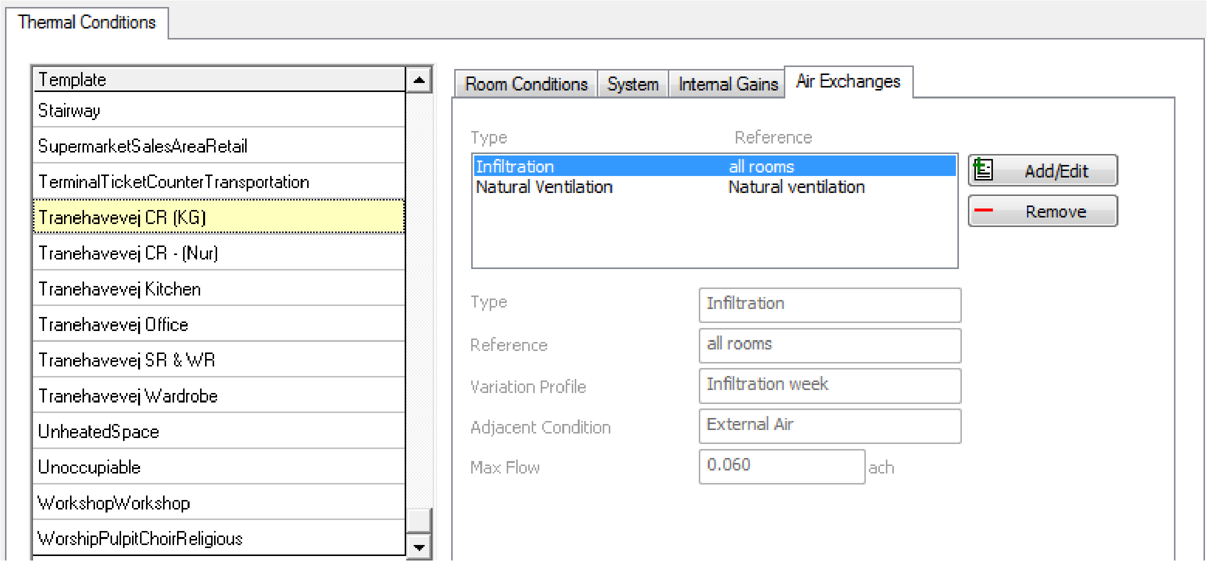
Units Type: ○ Metric ○ IP ● No units

	Time	Value
1	00:00	0.00
2	10:00	0.00
3	10:00	1.00
4	15:00	1.00
5	15:00	0.00
6	24:00	0.00

Figure 12 - Dimming profile kitchen.

Ventilation strategies

Infiltration



Template
Stairway
SupermarketSalesAreaRetail
TerminalTicketCounterTransportation
Tranehavevej CR (KG)
Tranehavevej CR - (Nur)
Tranehavevej Kitchen
Tranehavevej Office
Tranehavevej SR & WR
Tranehavevej Wardrobe
UnheatedSpace
Unoccupiable
WorkshopWorkshop
WorshipPulpitChoirReligious

Type	Reference
Infiltration	all rooms
Natural Ventilation	Natural ventilation

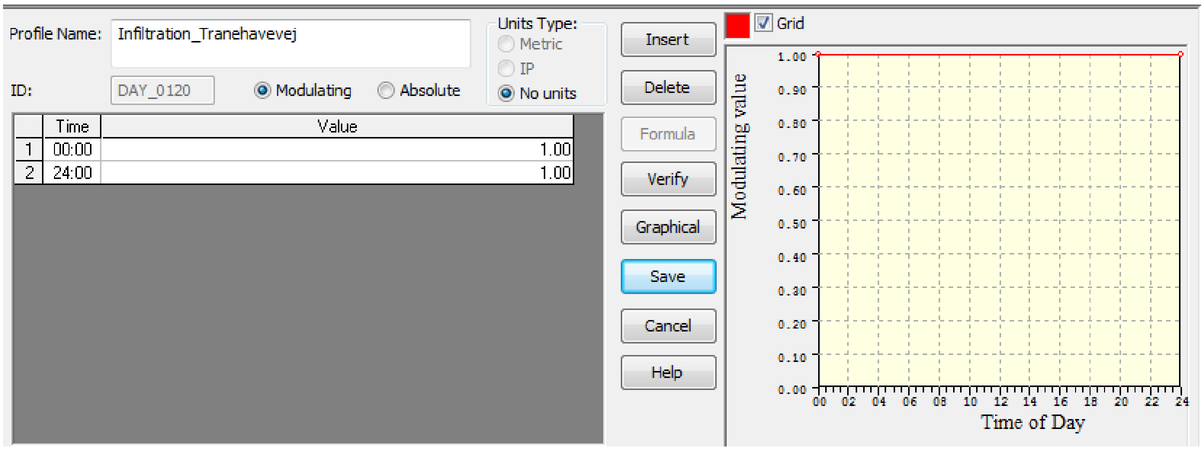
Type: Infiltration

Reference: all rooms

Variation Profile: Infiltration week

Adjacent Condition: External Air

Max Flow: 0.060 ach



Profile Name: Infiltration_Tranehavevej

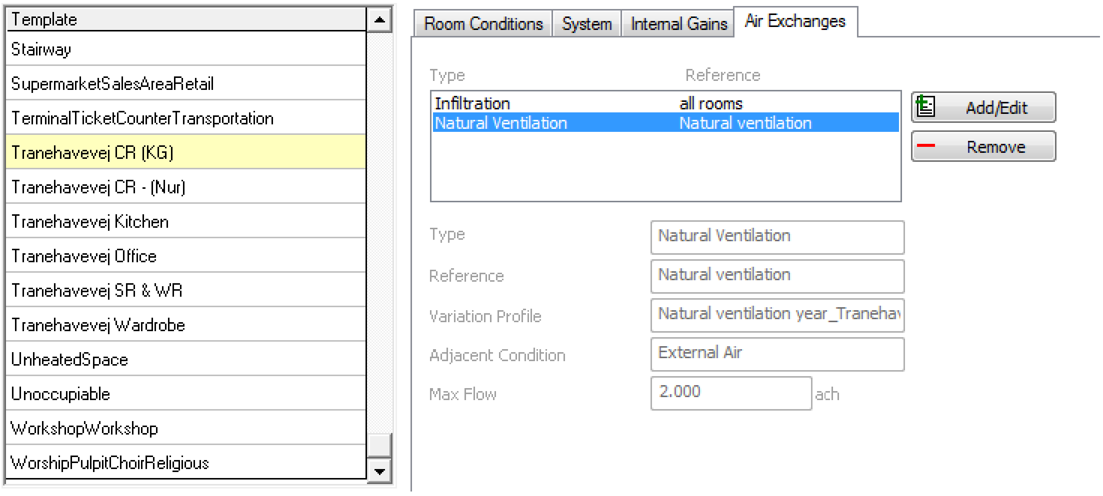
ID: DAY_0120 ● Modulating ○ Absolute

Units Type: ○ Metric ○ IP ● No units

	Time	Value
1	00:00	1.00
2	24:00	1.00

Figure 13 - Constant profile.

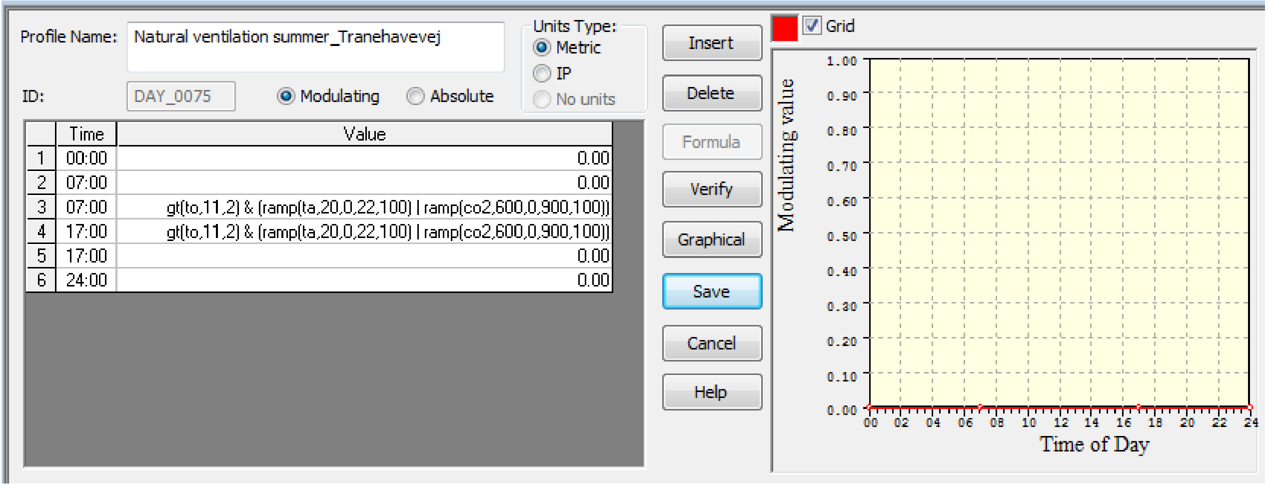
Natural ventilation



Template
Stairway
SupermarketSalesAreaRetail
TerminalTicketCounterTransportation
Tranehavevej CR (KG)
Tranehavevej CR - (Nur)
Tranehavevej Kitchen
Tranehavevej Office
Tranehavevej SR & WR
Tranehavevej Wardrobe
UnheatedSpace
Unoccupiable
WorkshopWorkshop
WorshipPulpitChoirReligious

Type	Reference
Infiltration	all rooms
Natural Ventilation	Natural ventilation

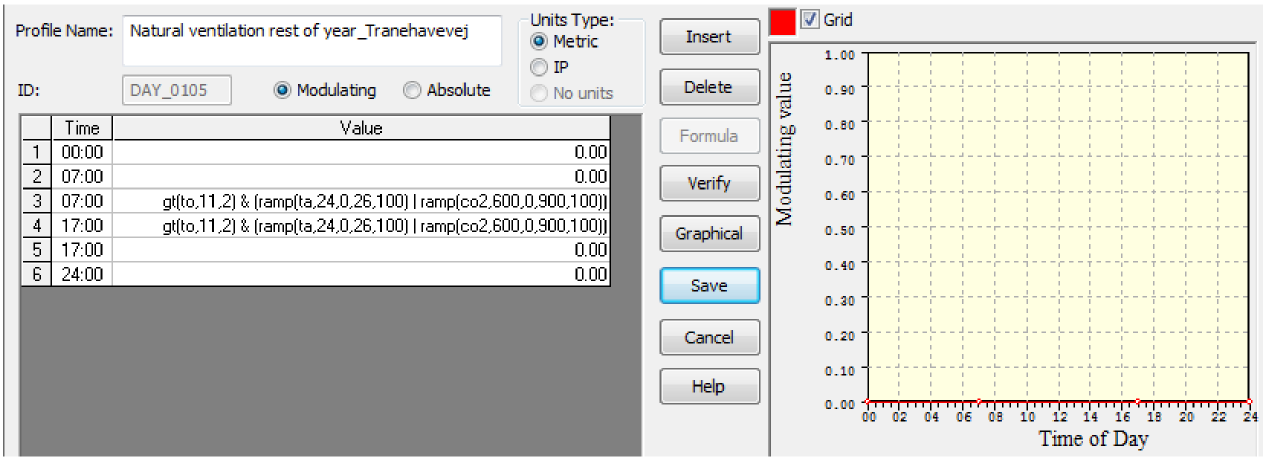
Type: Natural Ventilation
Reference: Natural ventilation
Variation Profile: Natural ventilation year_Tranehav
Adjacent Condition: External Air
Max Flow: 2.000 ach



Profile Name: Natural ventilation summer_Tranehavevej
ID: DAY_0075 ● Modulating ○ Absolute
Units Type: ● Metric ○ IP ○ No units

	Time	Value
1	00:00	0.00
2	07:00	0.00
3	07:00	gt(to,11,2) & (ramp(ta,20,0,22,100) | ramp(co2,600,0,900,100))
4	17:00	gt(to,11,2) & (ramp(ta,20,0,22,100) | ramp(co2,600,0,900,100))
5	17:00	0.00
6	24:00	0.00

Figure 14 - Natural ventilation summer (weekdays from Jun.-Aug.).



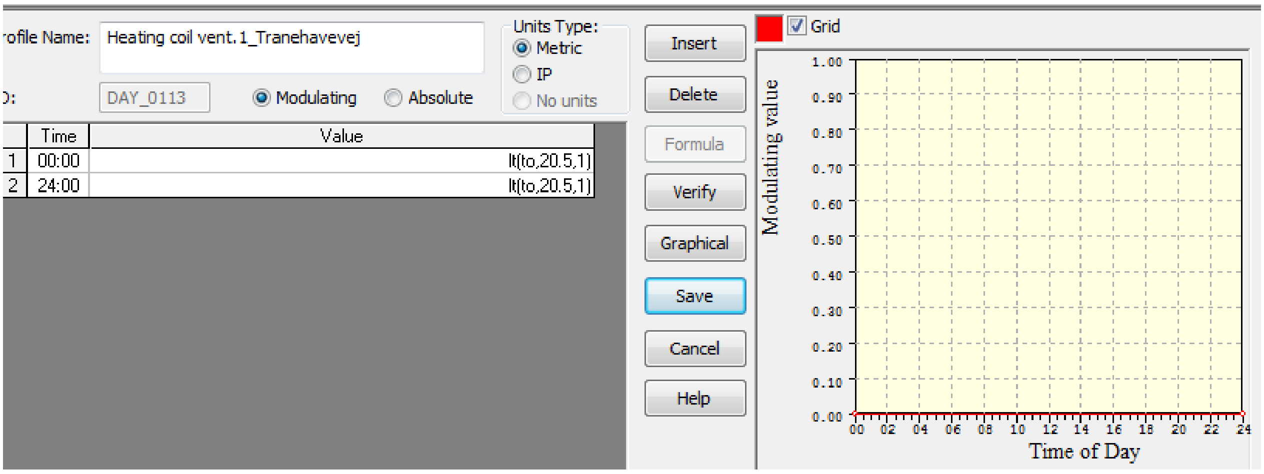
Profile Name: Natural ventilation rest of year_Tranehavevej
ID: DAY_0105 ● Modulating ○ Absolute
Units Type: ● Metric ○ IP ○ No units

	Time	Value
1	00:00	0.00
2	07:00	0.00
3	07:00	gt(to,11,2) & (ramp(ta,24,0,26,100) | ramp(co2,600,0,900,100))
4	17:00	gt(to,11,2) & (ramp(ta,24,0,26,100) | ramp(co2,600,0,900,100))
5	17:00	0.00
6	24:00	0.00

Figure 15 - Natural ventilation rest of the year during weekdays.

Mechanical ventilation

Heat recovery



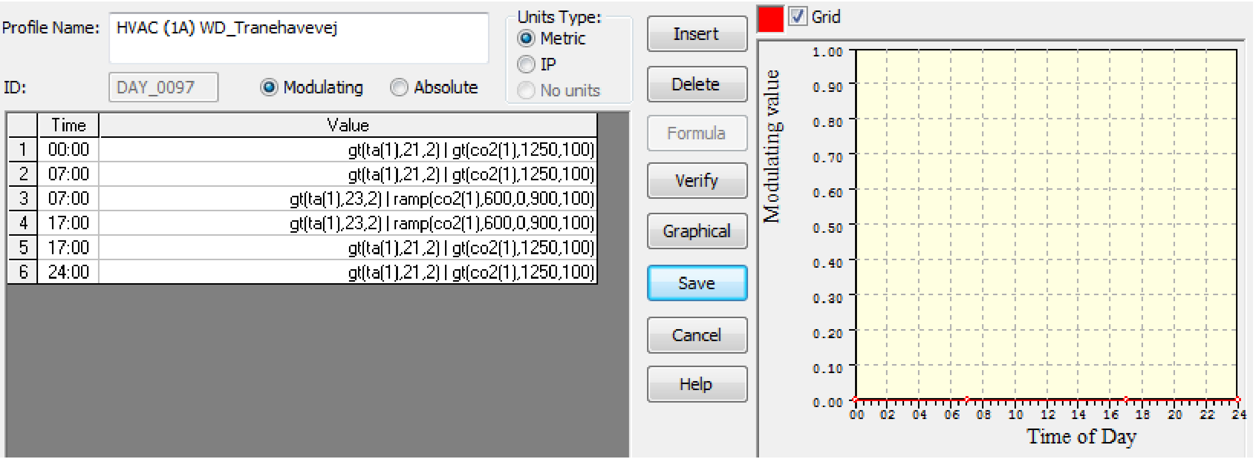
ofile Name: Heating coil vent.1_Tranehavevej

D: DAY_0113 ● Modulating ○ Absolute

Units Type: ● Metric ○ IP ○ No units

	Time	Value
1	00:00	lt(to,20.5,1)
2	24:00	lt(to,20.5,1)

Figure 16 – Heat recovery when the exterior temperature is below 20°C.



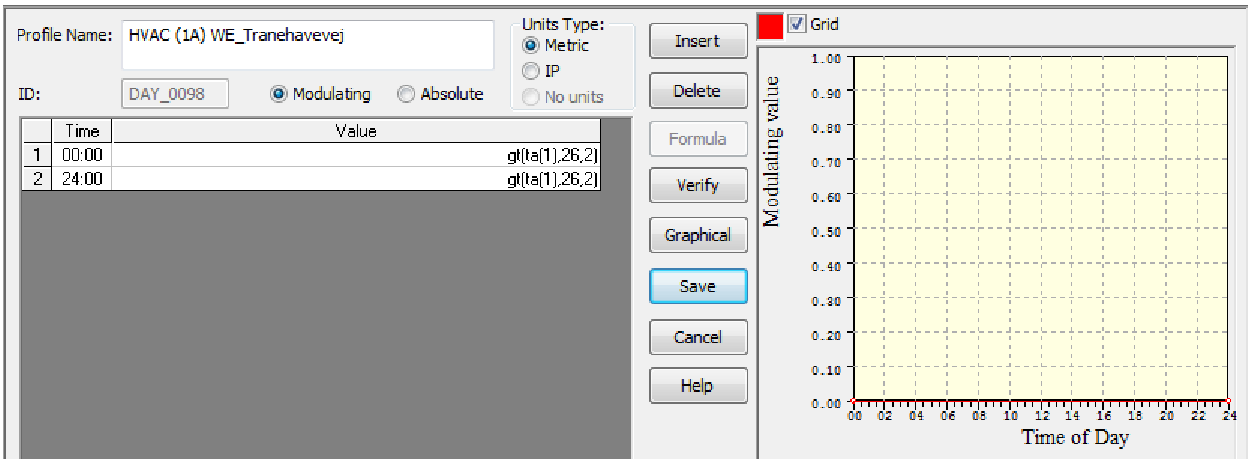
Profile Name: HVAC (1A) WD_Tranehavevej

ID: DAY_0097 ● Modulating ○ Absolute

Units Type: ● Metric ○ IP ○ No units

<table>
<tr><th></th><th>Time</th><th>Value</th></tr>
<tr><td>1</td><td>00:00</td><td>gt(ta(1),21,2) | gt(co2(1),1250,100)</td></tr>
<tr><td>2</td><td>07:00</td><td>gt(ta(1),21,2) | gt(co2(1),1250,100)</td></tr>
<tr><td>3</td><td>07:00</td><td>gt(ta(1),23,2) | ramp(co2(1),600,0,900,100)</td></tr>
<tr><td>4</td><td>17:00</td><td>gt(ta(1),23,2) | ramp(co2(1),600,0,900,100)</td></tr>
<tr><td>5</td><td>17:00</td><td>gt(ta(1),21,2) | gt(co2(1),1250,100)</td></tr>
<tr><td>6</td><td>24:00</td><td>gt(ta(1),21,2) | gt(co2(1),1250,100)</td></tr>
</table>

Figure 17 - Mechanical ventilation weekdays.



Profile Name: HVAC (1A) WE_Tranehavevej

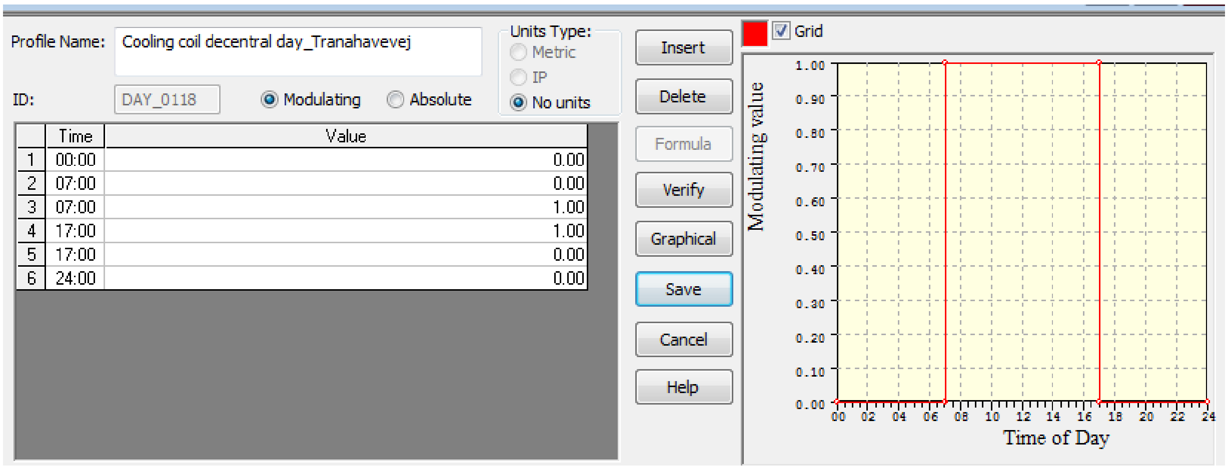
ID: DAY_0098 ● Modulating ○ Absolute

Units Type: ● Metric ○ IP ○ No units

	Time	Value
1	00:00	gt(ta(1),26,2)
2	24:00	gt(ta(1),26,2)

Figure 18 - Mechanical ventilation weekends.

Mechanical cooling



Profile Name: Cooling coil decentral day_Tranahavevej

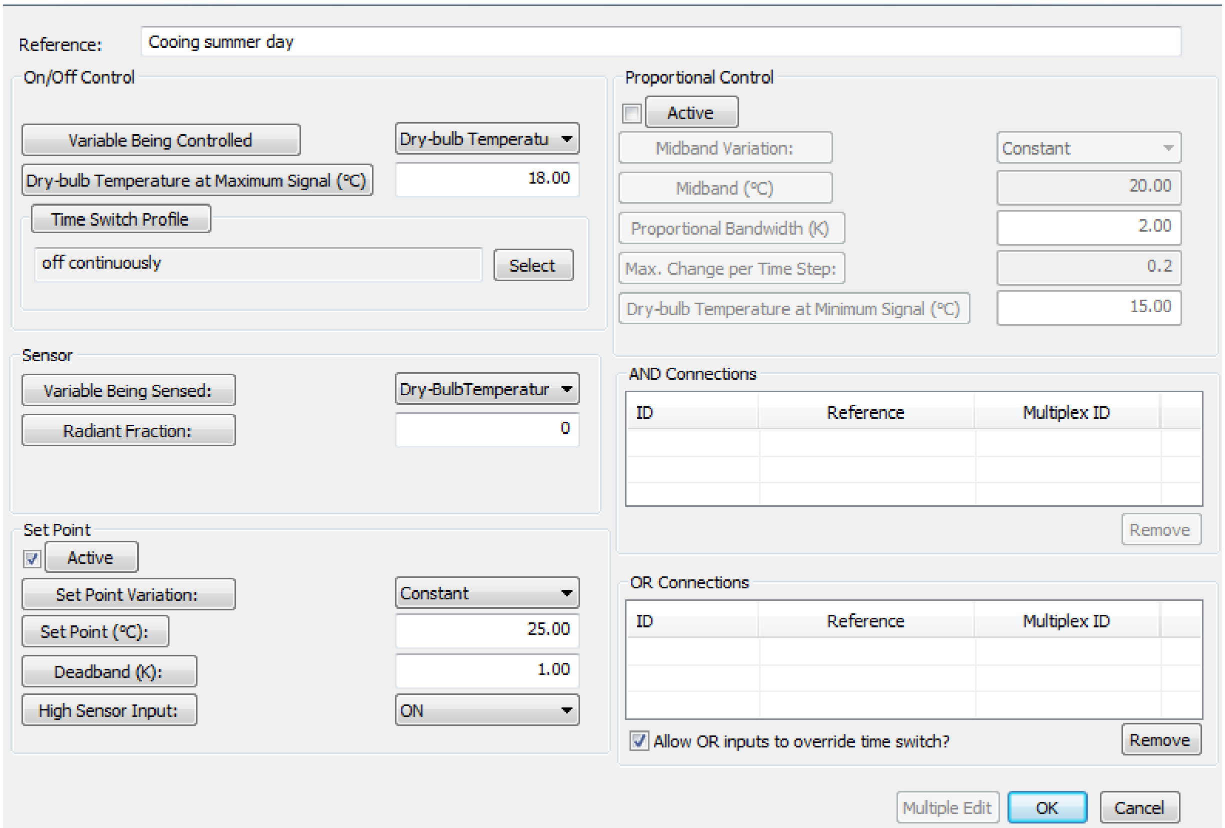
ID: DAY_0118 ● Modulating ○ Absolute

Units Type: ○ Metric ○ IP ● No units

	Time	Value
1	00:00	0.00
2	07:00	0.00
3	07:00	1.00
4	17:00	1.00
5	17:00	0.00
6	24:00	0.00

☑ Grid

Figure 19 - Cooling coil activation day.



Reference: Cooing summer day

On/Off Control

Variable Being Controlled: Dry-bulb Temperatu

Dry-bulb Temperature at Maximum Signal (°C): 18.00

Time Switch Profile: off continuously

Proportional Control

☐ Active

Midband Variation: Constant

Midband (°C): 20.00

Proportional Bandwidth (K): 2.00

Max. Change per Time Step: 0.2

Dry-bulb Temperature at Minimum Signal (°C): 15.00

Sensor

Variable Being Sensed: Dry-BulbTemperatur

Radiant Fraction: 0

AND Connections

ID	Reference	Multiplex ID

Set Point

☑ Active

Set Point Variation: Constant

Set Point (°C): 25.00

Deadband (K): 1.00

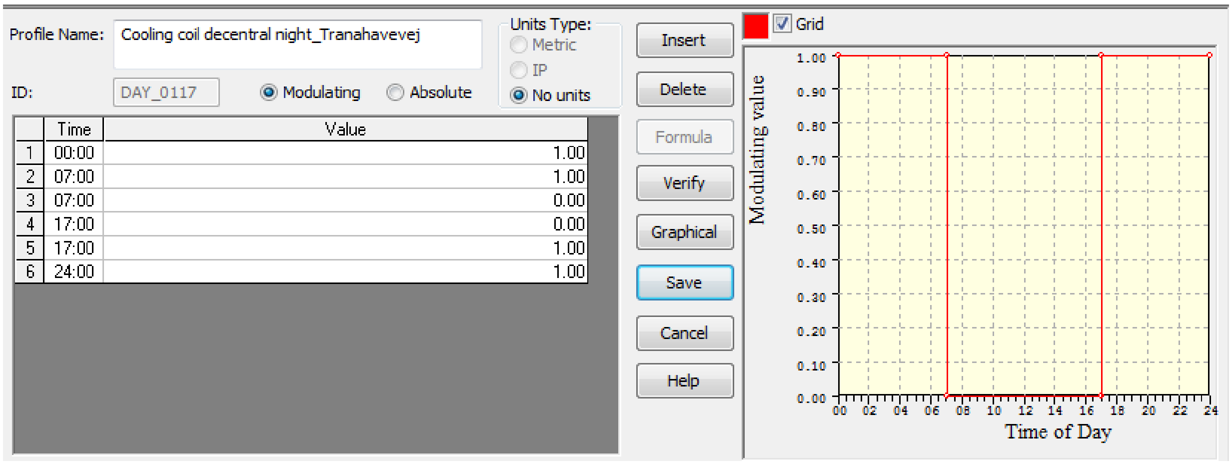
High Sensor Input: ON

OR Connections

ID	Reference	Multiplex ID

☑ Allow OR inputs to override time switch?

Figure 20 - Coolin coil set points.



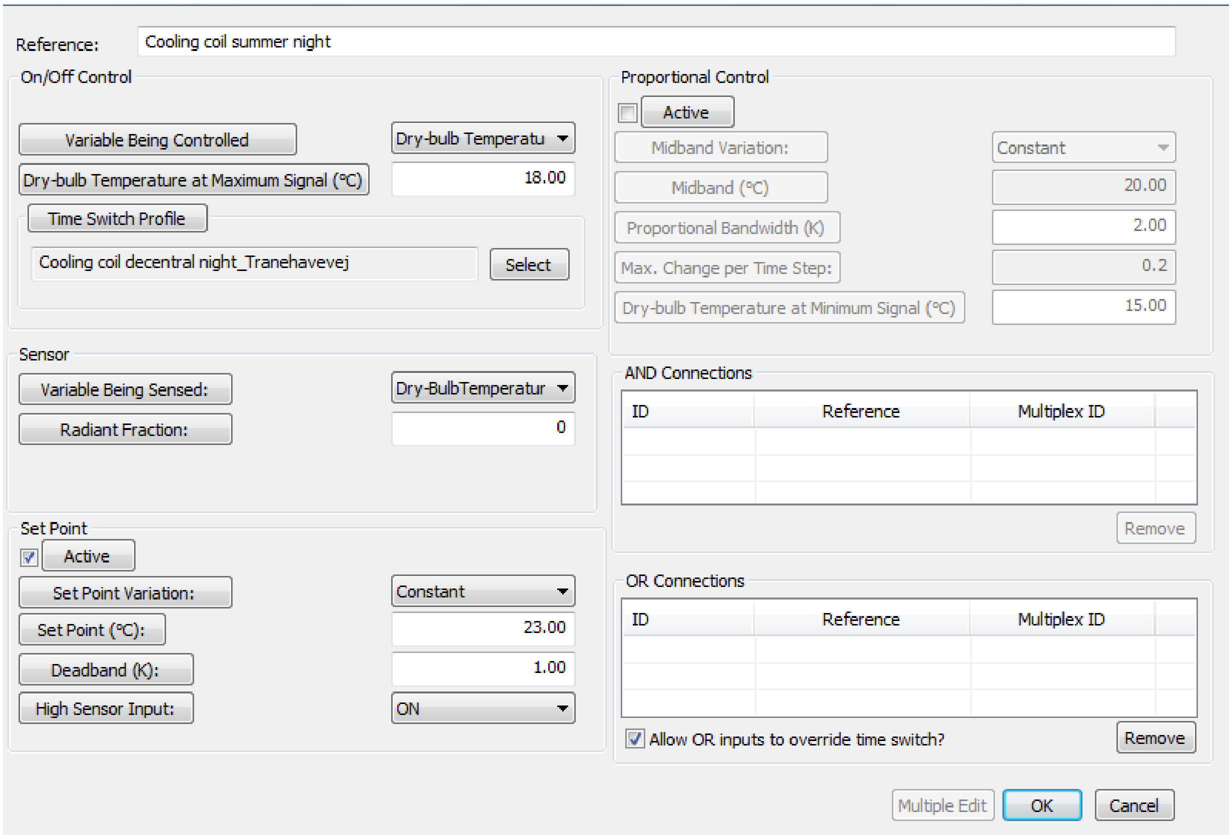
Profile Name: Cooling coil decentral night_Tranahavevej

ID: DAY_0117 ● Modulating ○ Absolute

Units Type: ○ Metric ○ IP ● No units

	Time	Value
1	00:00	1.00
2	07:00	1.00
3	07:00	0.00
4	17:00	0.00
5	17:00	1.00
6	24:00	1.00

Figure 21 - Cooling coil activation night.



Reference: Cooling coil summer night

On/Off Control

Variable Being Controlled: Dry-bulb Temperatu

Dry-bulb Temperature at Maximum Signal (°C): 18.00

Time Switch Profile: Cooling coil decentral night_Tranehavevej

Proportional Control

☐ Active

Midband Variation: Constant

Midband (°C): 20.00

Proportional Bandwidth (K): 2.00

Max. Change per Time Step: 0.2

Dry-bulb Temperature at Minimum Signal (°C): 15.00

Sensor

Variable Being Sensed: Dry-BulbTemperatur

Radiant Fraction: 0

AND Connections

ID	Reference	Multiplex ID

Set Point

☑ Active

Set Point Variation: Constant

Set Point (°C): 23.00

Deadband (K): 1.00

High Sensor Input: ON

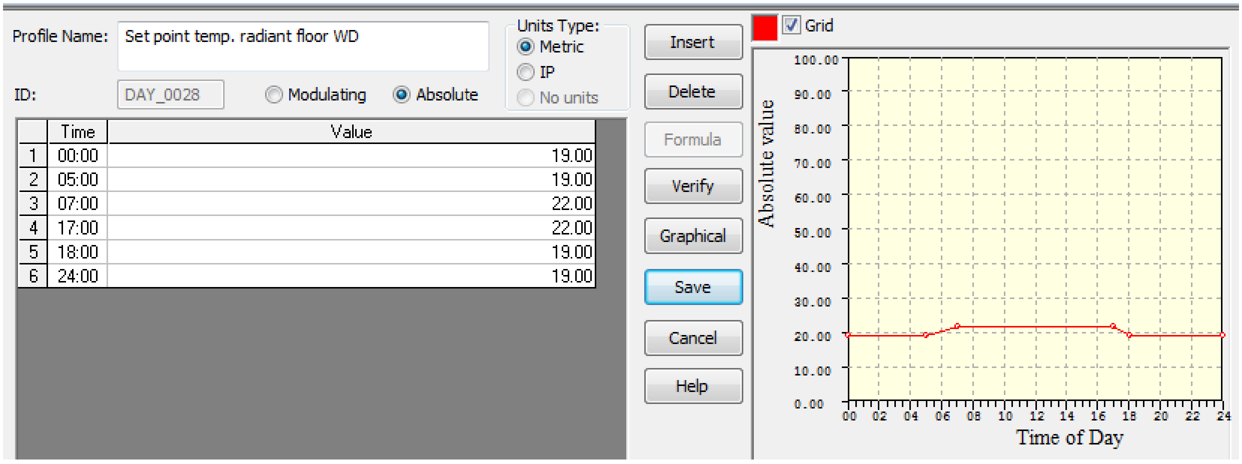
OR Connections

ID	Reference	Multiplex ID

☑ Allow OR inputs to override time switch?

Figure 22 - Cooling coil set points.

Radiant heating floor



Profile Name: Set point temp. radiant floor WD

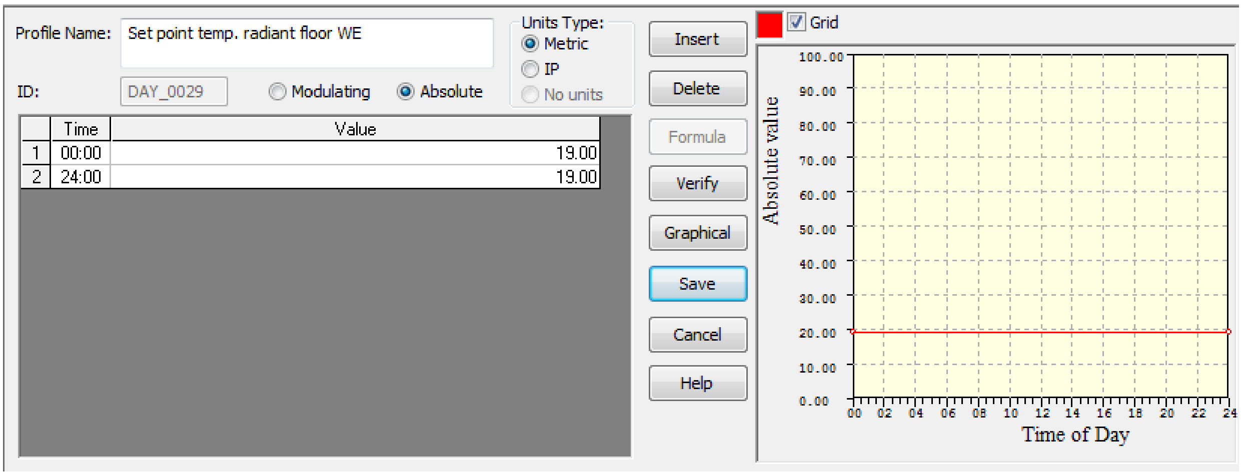
ID: DAY_0028 ○ Modulating ● Absolute

Units Type: ● Metric ○ IP ○ No units

	Time	Value
1	00:00	19.00
2	05:00	19.00
3	07:00	22.00
4	17:00	22.00
5	18:00	19.00
6	24:00	19.00

☑ Grid

Figure 23 - Set ponts radiant heating floor during the weekdays. The radiant heating floor is only active between middle of September – start of May.



Profile Name: Set point temp. radiant floor WE

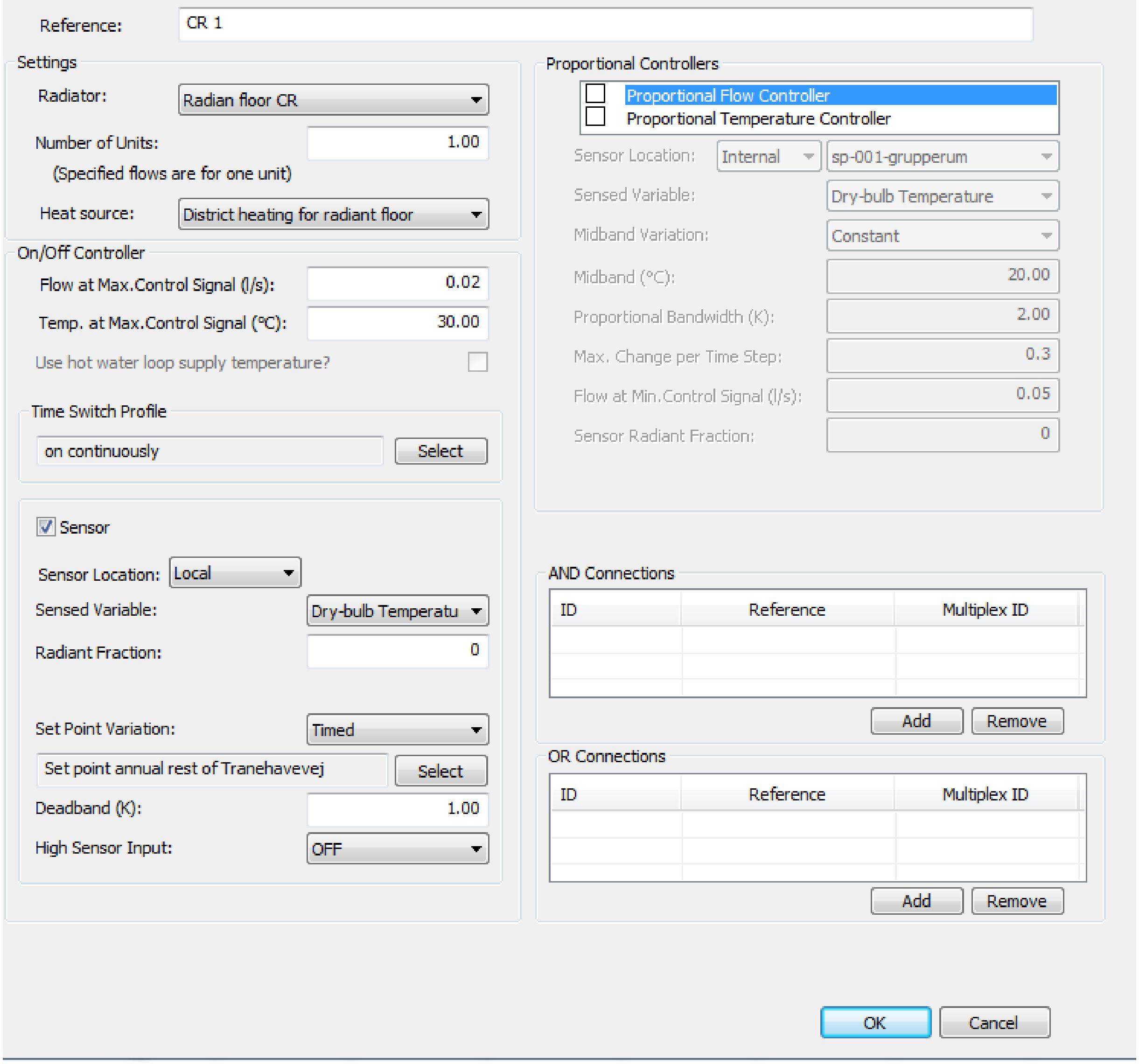
ID: DAY_0029 ○ Modulating ● Absolute

Units Type: ● Metric ○ IP ○ No units

	Time	Value
1	00:00	19.00
2	24:00	19.00

☑ Grid

Figure 24 - Set points radiant heating floor weekend.



Reference: CR 1

Settings

Radiator: Radian floor CR

Number of Units: 1.00

(Specified flows are for one unit)

Heat source: District heating for radiant floor

On/Off Controller

Flow at Max.Control Signal (l/s): 0.02

Temp. at Max.Control Signal (°C): 30.00

Use hot water loop supply temperature? ☐

Time Switch Profile

on continuously

☑ Sensor

Sensor Location: Local

Sensed Variable: Dry-bulb Temperatu

Radiant Fraction: 0

Set Point Variation: Timed

Set point annual rest of Tranehavevej

Deadband (K): 1.00

High Sensor Input: OFF

Proportional Controllers

☐ Proportional Flow Controller

☐ Proportional Temperature Controller

Sensor Location: Internal sp-001-grupperum

Sensed Variable: Dry-bulb Temperature

Midband Variation: Constant

Midband (°C): 20.00

Proportional Bandwidth (K): 2.00

Max. Change per Time Step: 0.3

Flow at Min.Control Signal (l/s): 0.05

Sensor Radiant Fraction: 0

AND Connections

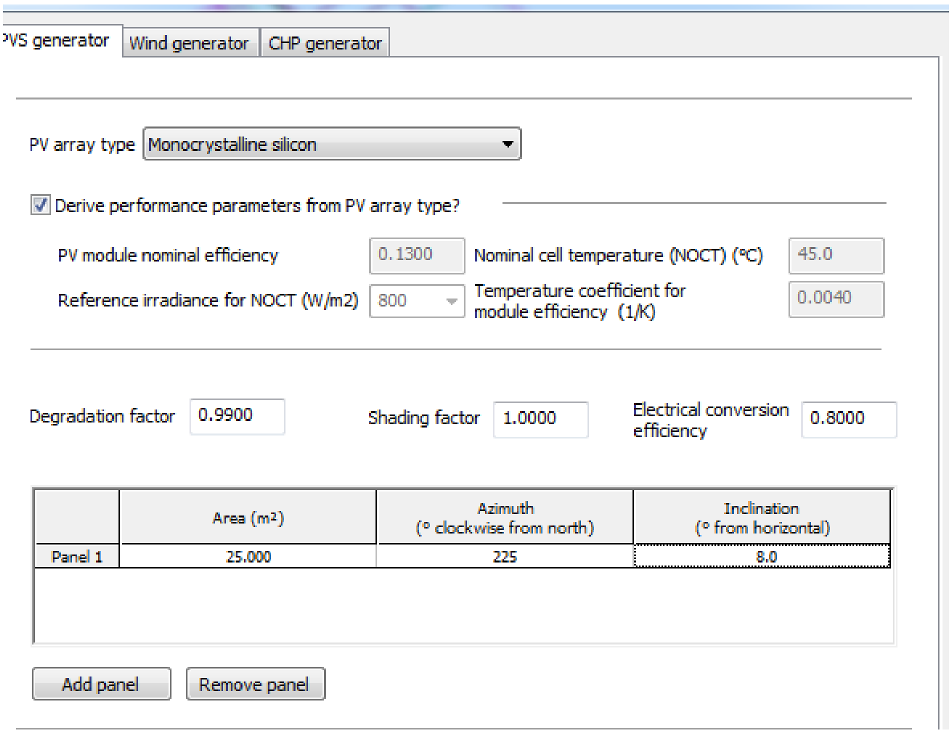
ID	Reference	Multiplex ID

OR Connections

ID	Reference	Multiplex ID

Figure 25 – Radiant heating floor control.

PV panels



PV array type: Monocrystalline silicon

☑ Derive performance parameters from PV array type?

PV module nominal efficiency: 0.1300

Nominal cell temperature (NOCT) (°C): 45.0

Reference irradiance for NOCT (W/m2): 800

Temperature coefficient for module efficiency (1/K): 0.0040

Degradation factor: 0.9900

Shading factor: 1.0000

Electrical conversion efficiency: 0.8000

	Area (m²)	Azimuth (° clockwise from north)	Inclination (° from horizontal)
Panel 1	25.000	225	8.0

Figure 26 – PV panel inputs.

Results

Energy consumption calculation

Areas: Total all five room: 195 m^2; only the three common rooms: 132 m^2.

Primary energy factors: electricity: 2.5; district heating: 0.8

Cooling: 1210 kWh/ 132 m^2 (three group rooms area) / 4 (COP) = 2.29 kWh/m^2

Total lights: 1150 kWh/ 195 m^2 = 5.9 kWh/m^2

ApHVAC distr. fans: 1605 kWh/ 195 m^2 = 8.23 kWh/m^2

Heating: 5562.4 kWh / 195 m^2 = 28.53 kWh/m^2

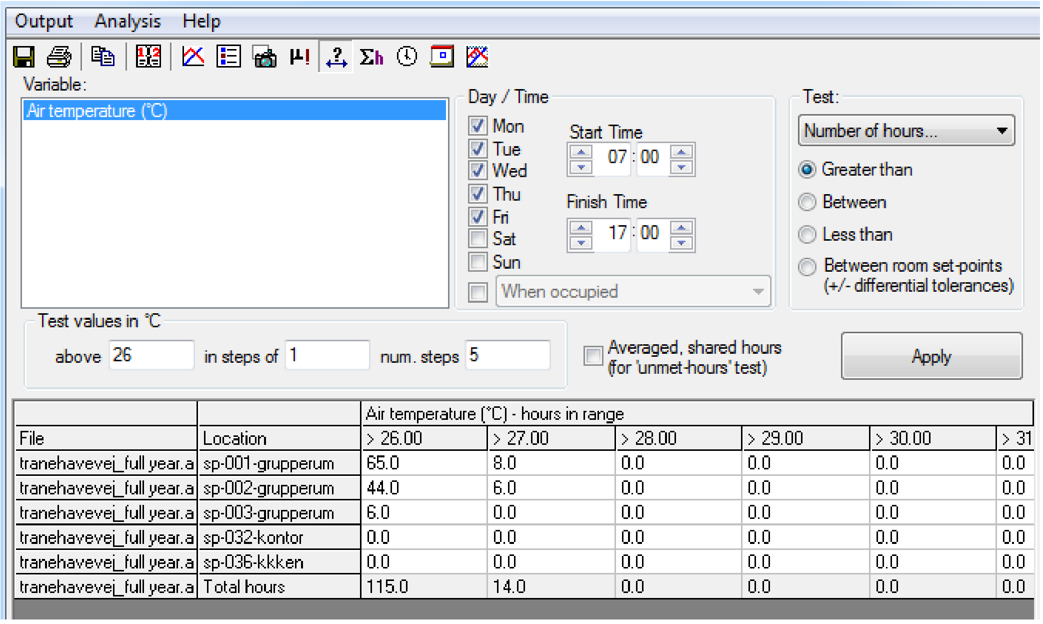
DHW: 5.23 kWh/m^2

PV panel: -2520.7 kWh for 10 m^2 to be divided over the entire building meaning that this should be multiplied with 0.2 because the simulated areas are 20% of the building and then divided out pr. Square meter: (-2520.7 kWh * 0.2) / 195 m^2 = -2.58 kWh/m^2

Summation: (2.29+5.90+8.23-2.58)*2.5 + (28.53*0.8) + 5.23 = 62.7 kWh/m^2

Thermal indoor climate

Overheating hours:



Variable: Air temperature (°C)

Day / Time

☑ Mon
☑ Tue
☑ Wed
☑ Thu
☑ Fri
☐ Sat
☐ Sun
☐ When occupied

Start Time 07 : 00

Finish Time 17 : 00

Test: Number of hours...

● Greater than
○ Between
○ Less than
○ Between room set-points (+/- differential tolerances)

Test values in °C

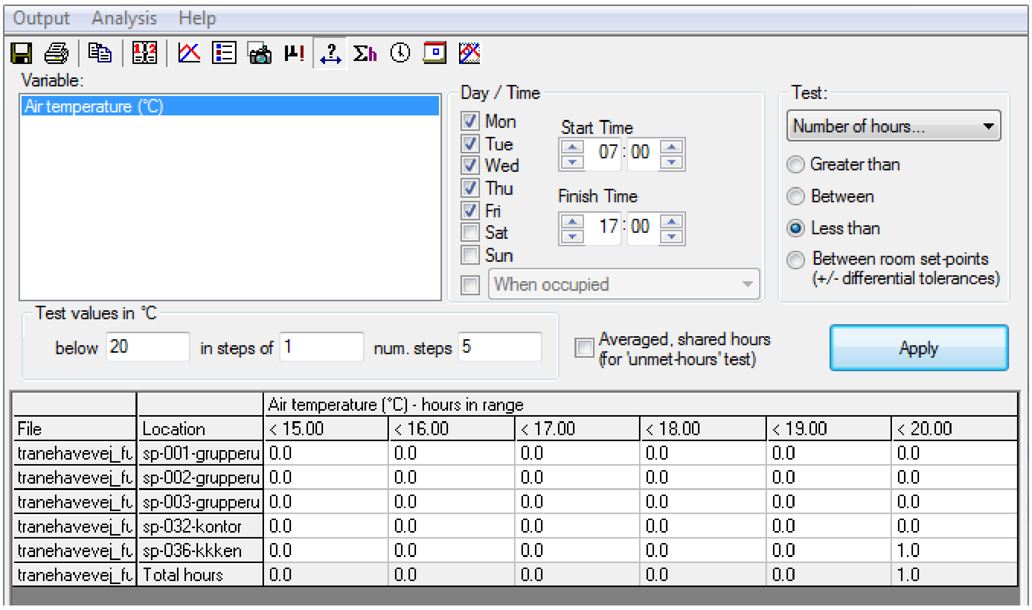
above 26 in steps of 1 num. steps 5

☐ Averaged, shared hours (for 'unmet-hours' test)

		Air temperature (°C) - hours in range					
File	Location	> 26.00	> 27.00	> 28.00	> 29.00	> 30.00	> 31
tranehavevej_full year.a	sp-001-grupperum	65.0	8.0	0.0	0.0	0.0	0.0
tranehavevej_full year.a	sp-002-grupperum	44.0	6.0	0.0	0.0	0.0	0.0
tranehavevej_full year.a	sp-003-grupperum	6.0	0.0	0.0	0.0	0.0	0.0
tranehavevej_full year.a	sp-032-kontor	0.0	0.0	0.0	0.0	0.0	0.0
tranehavevej_full year.a	sp-036-kkken	0.0	0.0	0.0	0.0	0.0	0.0
tranehavevej_full year.a	Total hours	115.0	14.0	0.0	0.0	0.0	0.0

Figure 27 – Overheating hours. It is seen during the institution's open hours of the year there are considerably less overheating than the required 100 hours > 26°C and 25 hours > 27°C in Br10.

Hours below 20°C:



Variable: Air temperature (°C)

Day / Time

☑ Mon
☑ Tue
☑ Wed
☑ Thu
☑ Fri
☐ Sat
☐ Sun
☐ When occupied

Start Time 07 : 00

Finish Time 17 : 00

Test: Number of hours...

○ Greater than
○ Between
● Less than
○ Between room set-points (+/- differential tolerances)

Test values in °C

below 20 in steps of 1 num. steps 5

☐ Averaged, shared hours (for 'unmet-hours' test)

		Air temperature (°C) - hours in range					
File	Location	< 15.00	< 16.00	< 17.00	< 18.00	< 19.00	< 20.00
tranehavevej_fu	sp-001-grupperu	0.0	0.0	0.0	0.0	0.0	0.0
tranehavevej_fu	sp-002-grupperu	0.0	0.0	0.0	0.0	0.0	0.0
tranehavevej_fu	sp-003-grupperu	0.0	0.0	0.0	0.0	0.0	0.0
tranehavevej_fu	sp-032-kontor	0.0	0.0	0.0	0.0	0.0	0.0
tranehavevej_fu	sp-036-kkken	0.0	0.0	0.0	0.0	0.0	1.0
tranehavevej_fu	Total hours	0.0	0.0	0.0	0.0	0.0	1.0

Figure 18 – Hours below 20°C: There is only one hour below 20°C in during the opening period of the year.

Examples of indoor climate

Common room 1

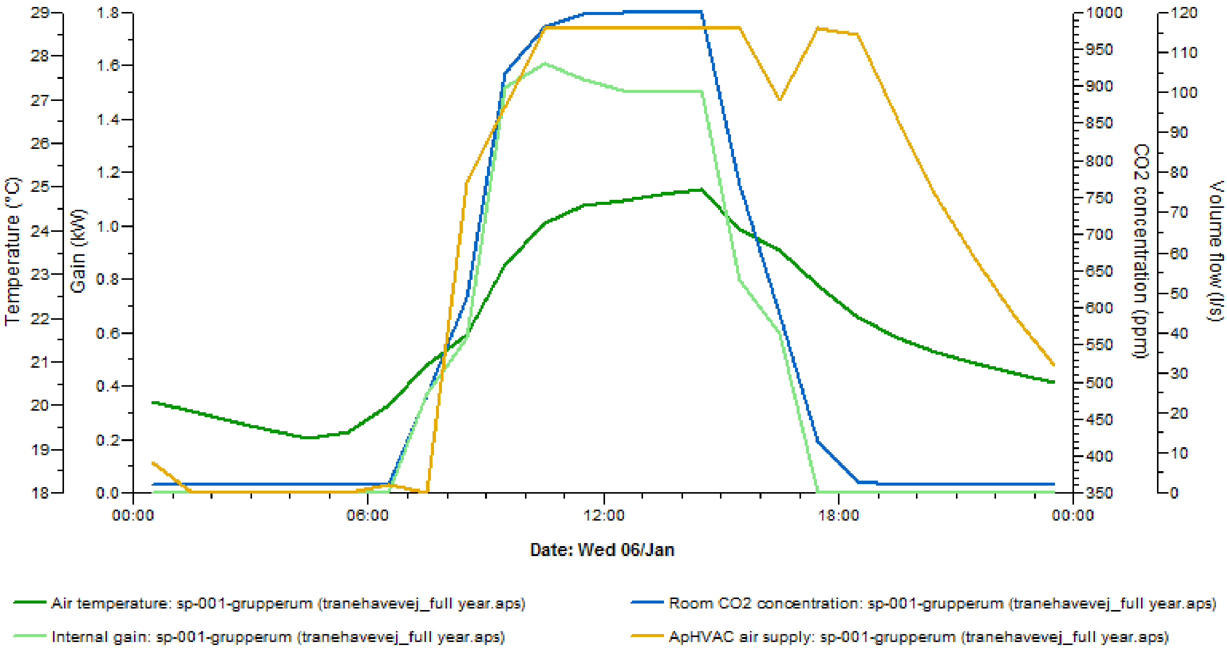


Figure 29 – Winter day situation. temperature (green), internal gain (light green), CO_2 concentration (blue) and ventilation rate (yellow)

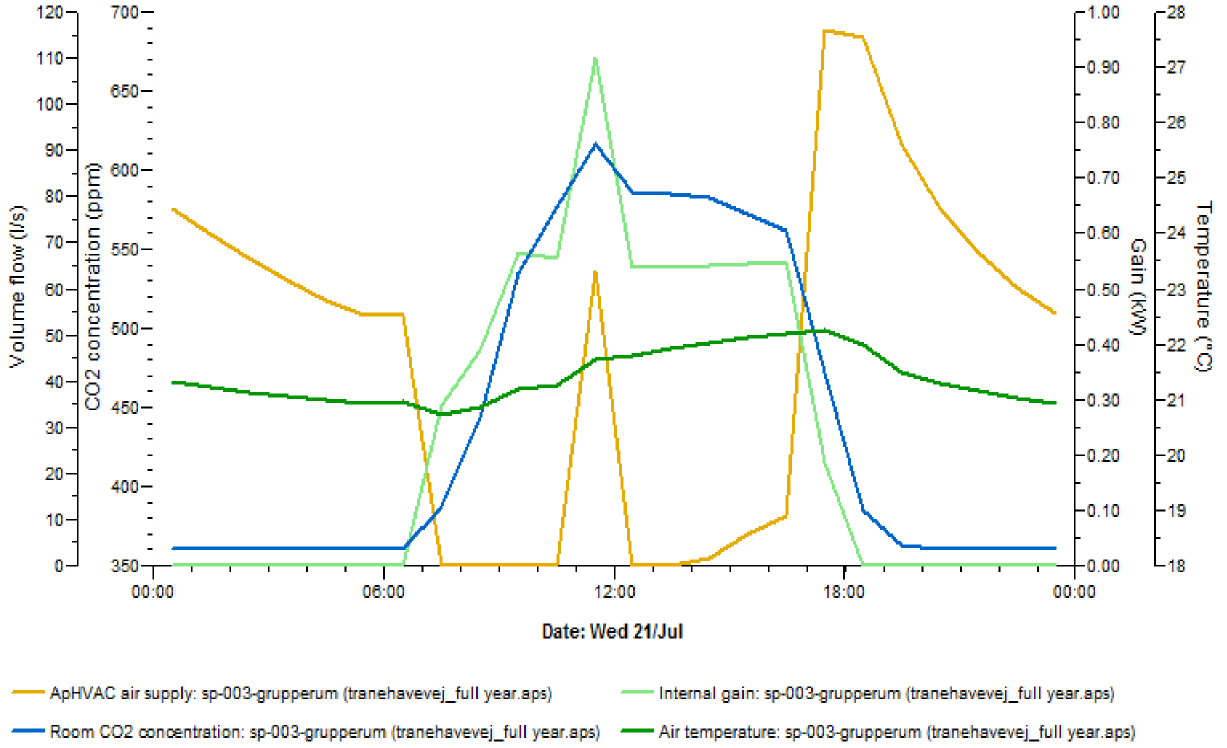


Figure 30 – Summer day situation. temperature (green), internal gain (light green), CO_2 concentration (blue) and ventilation rate (yellow)

Kitchen

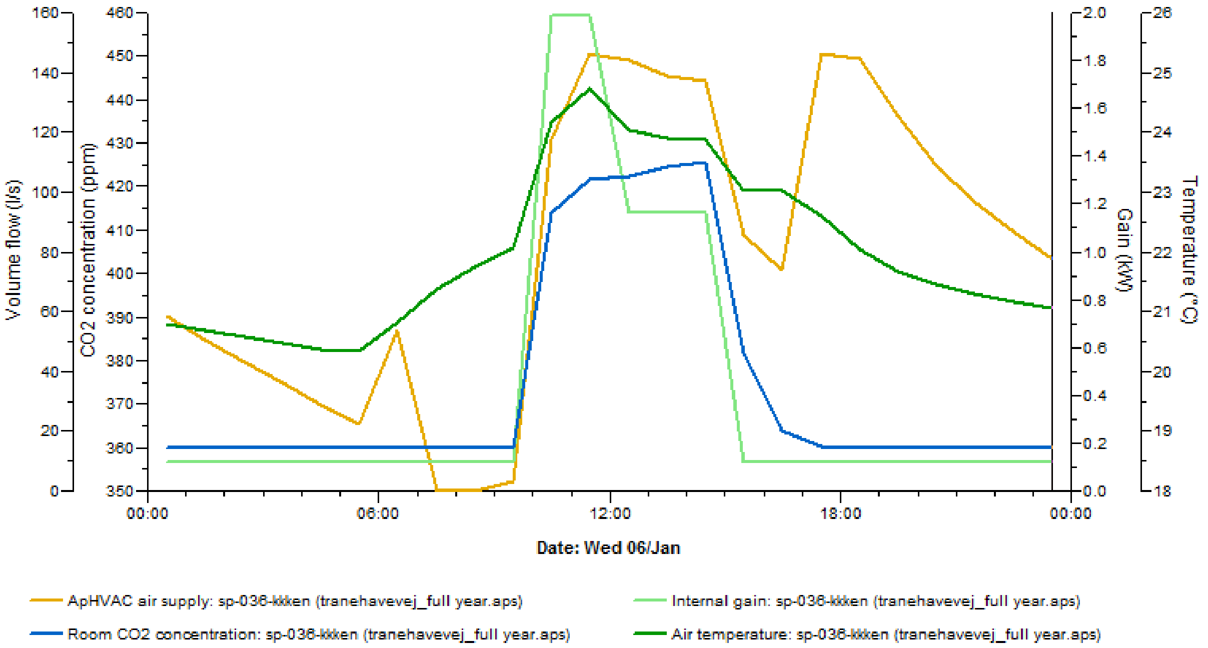


Figure 31 – Winter day situation. temperature (green), internal gain (light green), CO_2 concentration (blue) and ventilation rate (yellow)

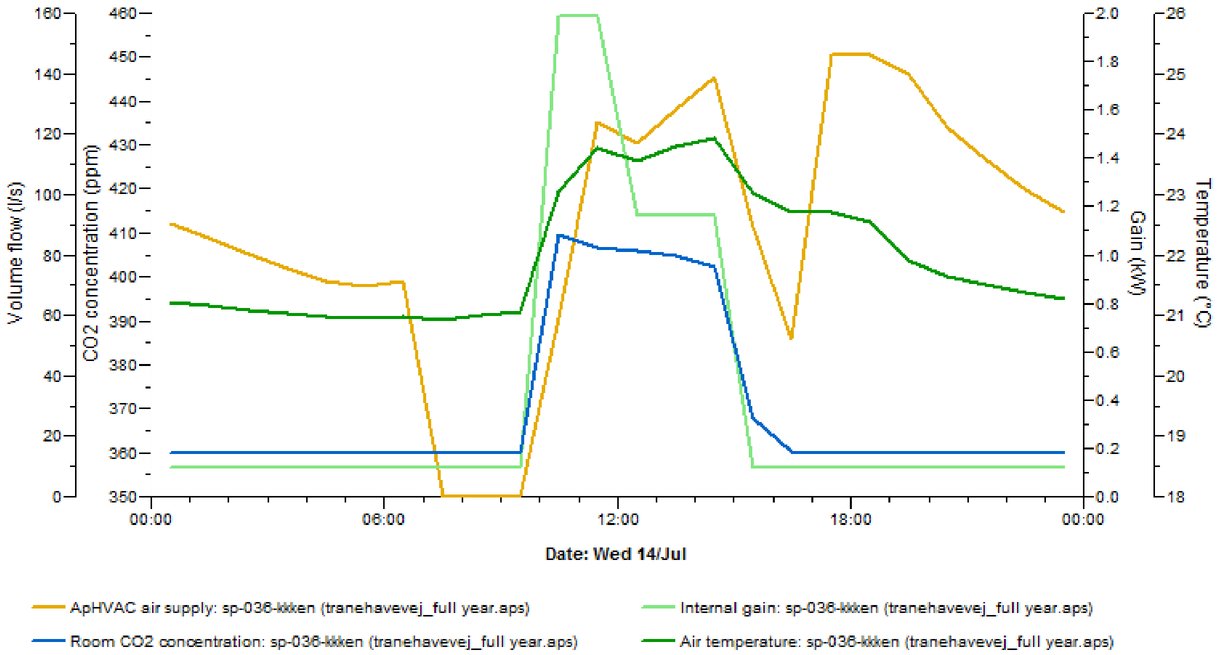


Figure 32 – Summer day situation. temperature (green), internal gain (light green), CO_2 concentration (blue) and ventilation rate (yellow)

Office

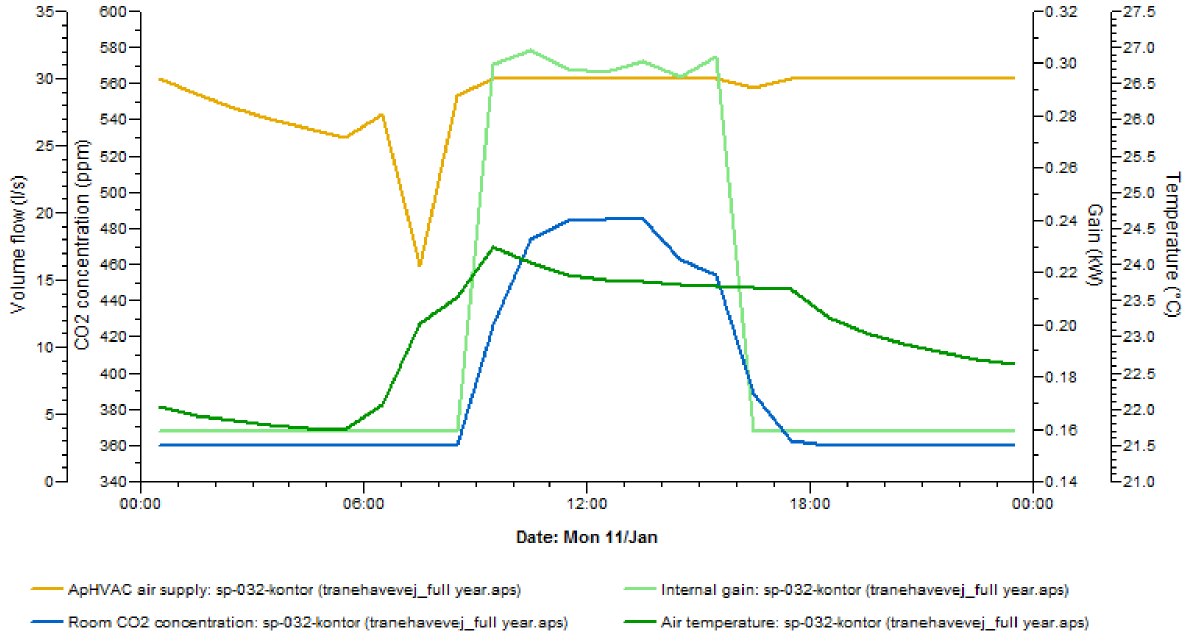


Figure 33 – Winter day situation. temperature (green), internal gain (light green), CO_2 concentration (blue) and ventilation rate (yellow)

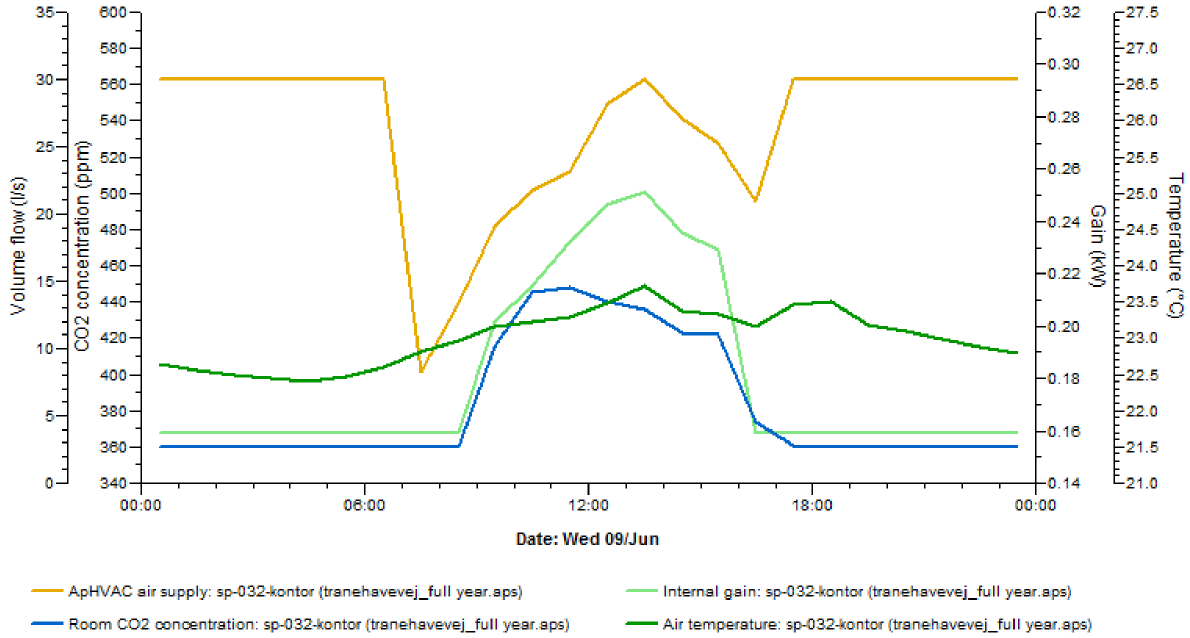
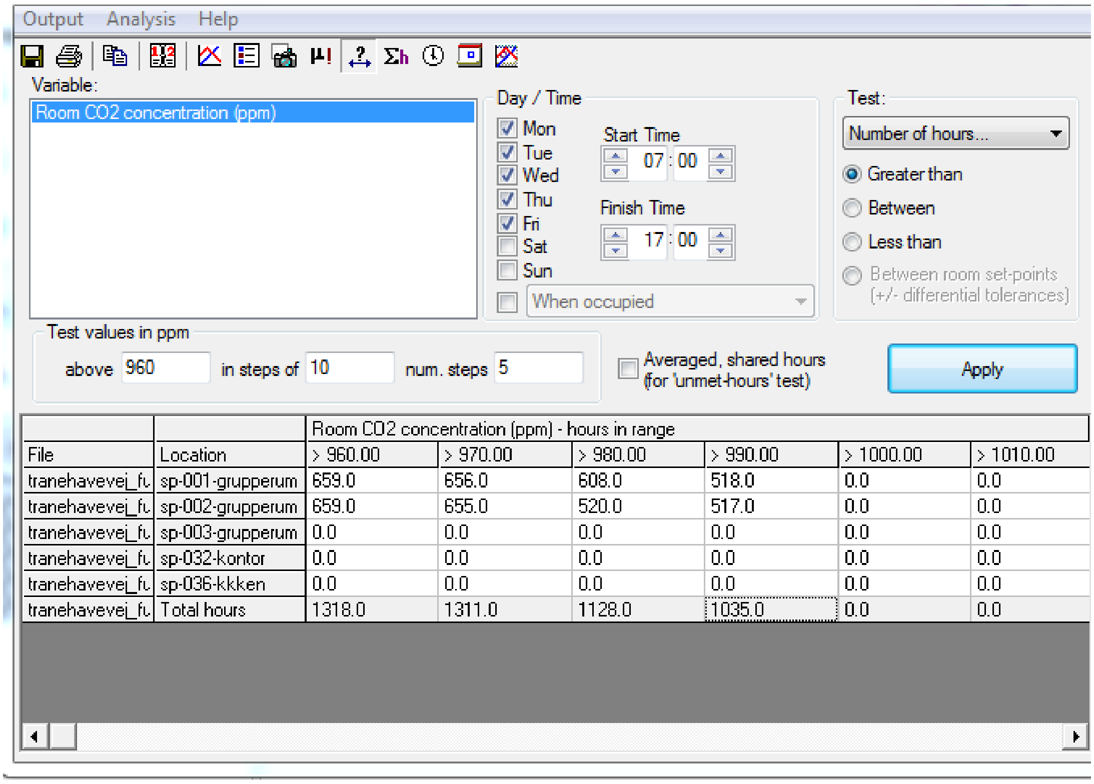


Figure 34 – Summer day situation. temperature (green), internal gain (light green), CO_2 concentration (blue) and ventilation rate (yellow)

Atmospheric indoor climate



Variable:
Room CO2 concentration (ppm)

Day / Time
☑ Mon
☑ Tue
☑ Wed
☑ Thu
☑ Fri
☐ Sat
☐ Sun
☐ When occupied

Start Time 07 : 00
Finish Time 17 : 00

Test:
Number of hours...
● Greater than
○ Between
○ Less than
○ Between room set-points (+/- differential tolerances)

Test values in ppm
above 960 in steps of 10 num. steps 5

☐ Averaged, shared hours (for 'unmet-hours' test)

		Room CO2 concentration (ppm) - hours in range					
File	Location	> 960.00	> 970.00	> 980.00	> 990.00	> 1000.00	> 1010.00
tranehavevej_fu	sp-001-grupperum	659.0	656.0	608.0	518.0	0.0	0.0
tranehavevej_fu	sp-002-grupperum	659.0	655.0	520.0	517.0	0.0	0.0
tranehavevej_fu	sp-003-grupperum	0.0	0.0	0.0	0.0	0.0	0.0
tranehavevej_fu	sp-032-kontor	0.0	0.0	0.0	0.0	0.0	0.0
tranehavevej_fu	sp-036-kkken	0.0	0.0	0.0	0.0	0.0	0.0
tranehavevej_fu	Total hours	1318.0	1311.0	1128.0	1035.0	0.0	0.0

Figure 35 – CO$_2$ concentration results.

Examples of Atmospheric indoor climate

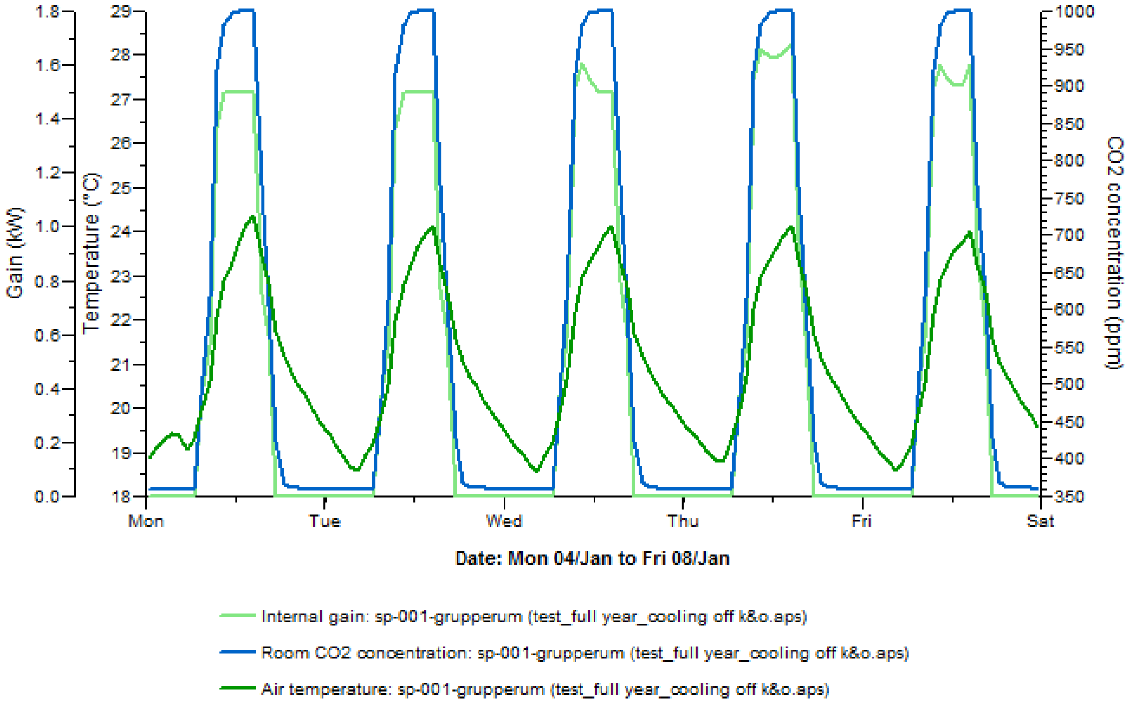


Figure 36 – CO$_2$ concentrations, interior temperature and internal gains in common room 1 in a winter week.

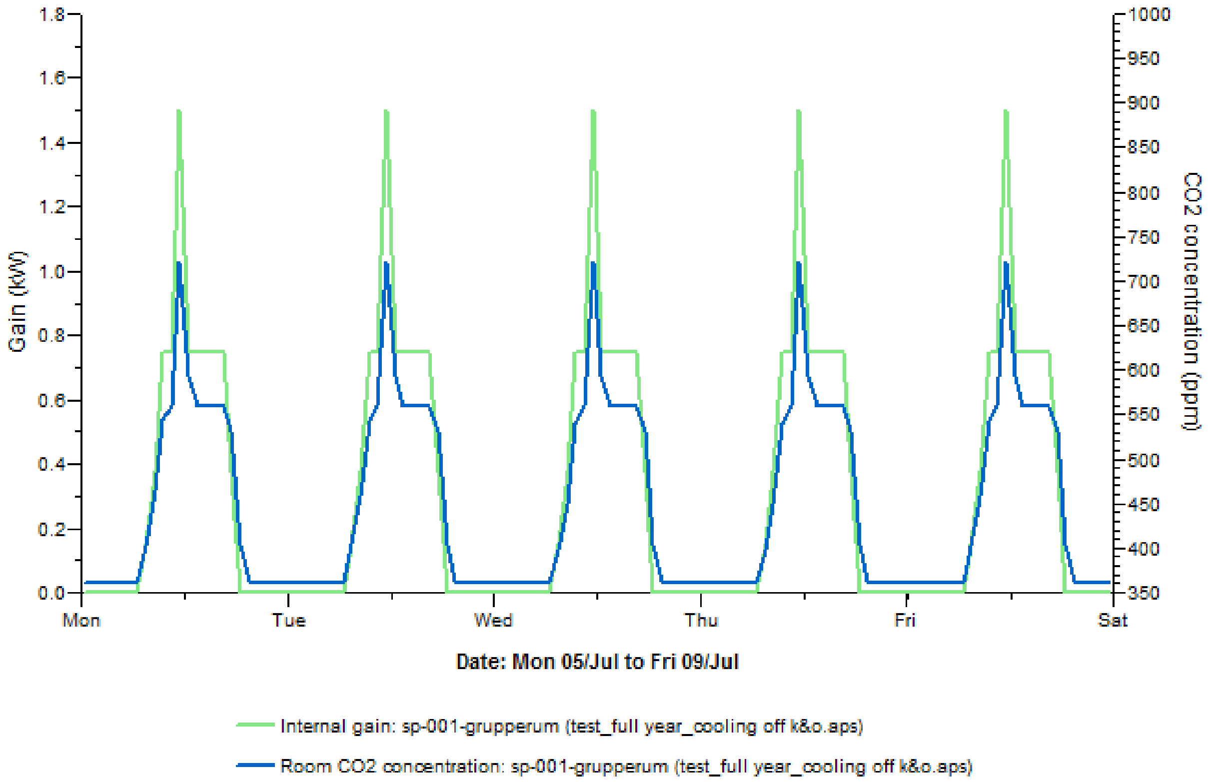


Figure 37 – CO_2 concentrations and internal gains in common room 1 in a summer week.

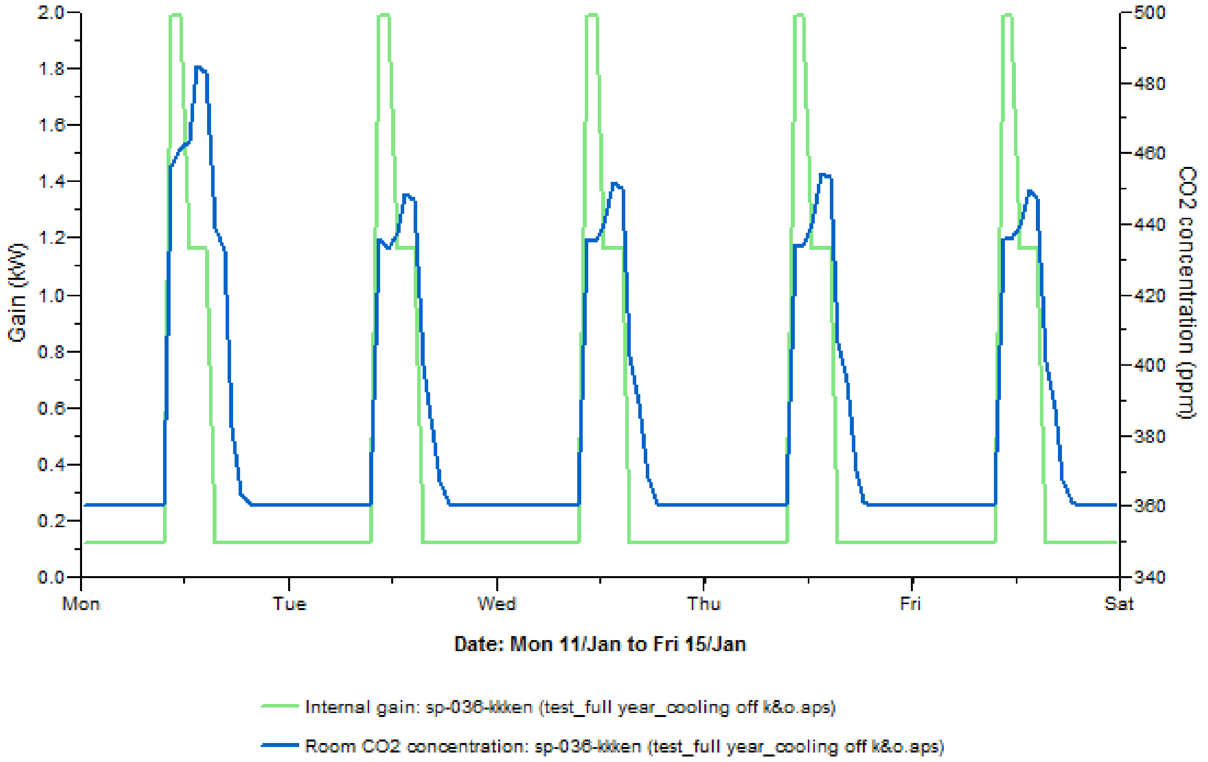


Figure 38 – CO_2 concentrations and internal gains in the kitchen in a winter week.

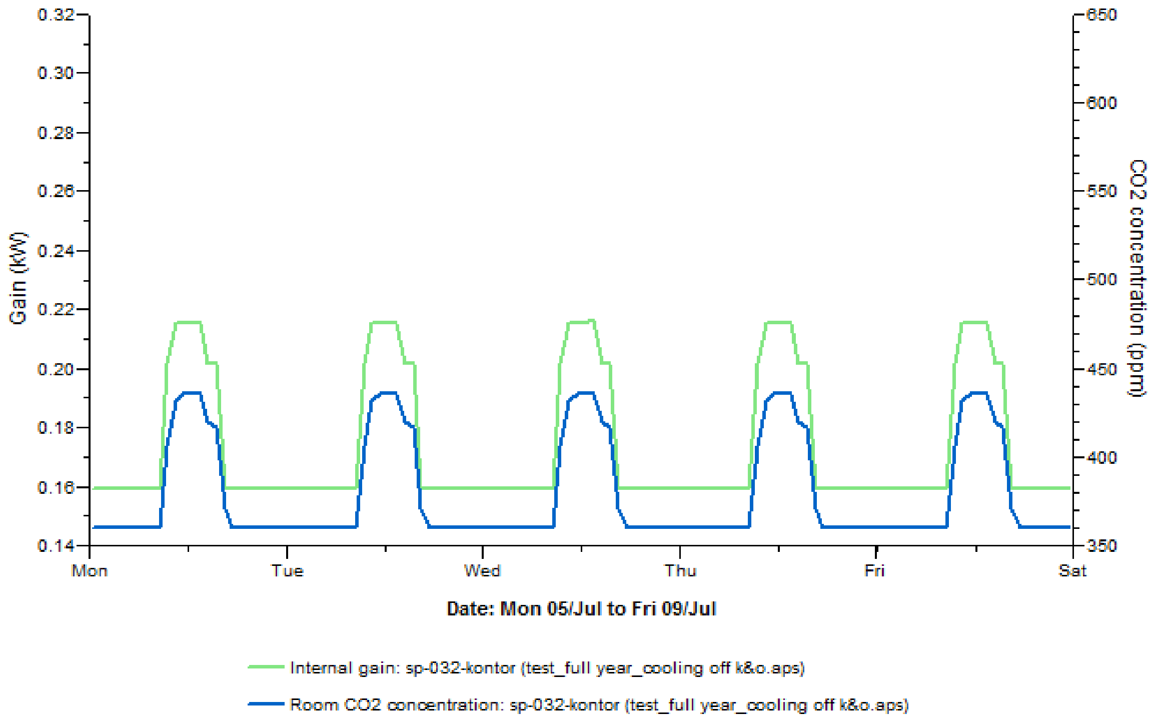


Figure 39 – CO_2 concentrations and internal gains in the office in a summer week.

Be10 tailored according to IES<VE> results

Example of changed ventilation rate during winter from the original Be10 calculation for one of the common rooms ($44m^2$; $144m^3$):

Conversion from $l/(s*m^2)$ to air change pr. hour:

$0.74\ l/(s*m^2) * 3.6\ m^3/h = 2.664\ m^3/(h*m^2) \rightarrow 2.664\ m^3/(h*m^2) * 44m^2 = 117.2\ m^3/h \rightarrow 117.2\ m^3/h / 144m^3 = 1.76\ h^{-1}$

The Bsim and IES<VE> calculations have proved a need for $3h^{-1}$ VAV ventilation:

$3h^{-1} * 144m^3 = 432\ m^3/h \rightarrow 432\ m^3/h / 44m^2 = 9.81\ m^3/(h*m^2) \rightarrow 9.81\ m^3/(h*m^2) / 3.6\ m^3/h = 2.7\ l/(s*m^2)$

This is the air change if the ventilation was $3h^{-1}$ the entire time from 7 a.m.-5p.m. but in reality this will vary over the course of the day so a factor of 0.8 is multiplied on this during winter resulting in: 2.2 $l/(s*m^2)$. During summer where the internal gains are no as intense over the course of the entire day because the occupants are expected to be outside much of the time the factor used here is 0.65 resulting in 1.8 $l/(s*m^2)$.

Based on the same procedure other rooms that have been dealt with have the following air changes (the reduction factor for usage time is the same here because these rooms are expected to be used similarly winter and summer):

	Factor	Air change [h^{-1}]
Kitchen ($3h^{-1}$):	0.4 for reduction in usage time	1
Office ($3h^{-1}$):	0.5 for reduction in usage time	0.6

The usage time has been chosen to remain the same as in the original model on thereby incorporate this into the air change instead. In the rest of the rooms the air change rates remains unchanged.

Skylights

The windows has been changed since the original Be10 calculation was made, because it was decided to use a window with a g-value of 0.43 and no solar shading on the skylights as opposed to the original choice with a g-value of 0.57 (similar to the façade windows) and internal solar shading.

Internal heat gains

There are 102 person (children and adults) on in the institution if everyone is there at the same time. These have an average heat production of 76W for the mix of larger kids and adults (50% of the building) and 60W for the mix of smaller kids and adults (50%). Together this is approx. 68W. This is to be multiplied by the number of persons and divided by the floor area → (68W*102 pers.)/ 977 m^2 ~ 7 W/m^2.

Equipment kitchen calculated to 50.5 W/m^2 when everything is in use at once, but this is only a very little portion of the day that this will take place so a factor of 0.2 is multiplied on this giving: ~10W/m^2.

Lighting

Correction of lux level from the original model to the tailored based on standard DS/EN 15251:

	Original Be10 [Lux]	Tailored
Office:	200	500
Kitchen:	200	300

Cooling

Since the dynamic simulations showed that cooling was necessary mechanical cooling has been added to the tailored Be10 calculation. The COP factor of the cooling system in the ventilation has been set to 4.

Adjustments made in IES<VE>

Light transmittance adjustments between Revit and IES<VE>

Due to the simplifications that take place in the transfer between Revit and IES<VE> (when choosing the “Simple with shading surfaces” option in the IES<VE> plug-in) the frame construction is neglected in IES<VE> which means that this becomes either glass or wall/roof area. The following are calculations of reduced/increased glass area in the imported model for the common room in IES<VE> and how the light transmittance (LT) is changed in order to compensate for this. The adjustments are used in the glass construction properties and in the Radiance module to calculate the correct amount of daylight in a certain room.

Façade

Window next to glass door:

Glass area in Bsim model: 3.26 m
Glass area in IES<VE> model: 3.14 m
Reduction: ((3.26-3.14)/3.14)*100 = 3.8 %
Factor: 1 + 0.038 = 1.038
Real LT value in project: 0.73
Adjusted LT to compensate for changed glass area: 0.73 * 1.038 = 0.75 (equals: 42 % of 2 windows)

Small and large window next to pergola (combined in the transfer to IES<VE>):

Glass area in Bsim model: 3.67 m
Glass area in IES<VE> model: 4.26 m
Increase: ((4.26+3.67)/3.67)*100 = 16.1 %
Factor: 3.67/4.26 = 0.86
Real LT value in project: 0.73
Adjusted LT to compensate for changed glass area: 0.73 * 0.86 = 0.63 (Equals: 58 % of 2 windows)

Combined LT value for the above two window types: 0.75*0.42+0.63*0.58 = **0.68**
(this value is used for all windows in building except for the types listed below).

Glass door in Common room:

Glass area in Bsim model: 1. 52 m
Glass area in IES<VE> model: 2.26 m
Reduction: ((2.26+1.52)/1.52)*100 = 48.7 %
Factor: 1.52/2.26 = 0.67
Real LT value in project: 0.73
Adjusted LT to compensate for changed glass area: 0.73 * 0.67 = **0.49**

Skylights

Glass area in Bsim model: 2.20 m
Glass area in IES<VE> model: 2.66 m
Reduction: ((2.66+2.2)/2.20)*100 = 20.9 %
Factor: 2.20/2.66 = 0.83
Real LT value in project: 0.43
Adjusted LT to compensate for changed glass area: 0.43 * 0.83 = **0.36**

Daylight sensor settings in IES<VE>

Sensors are used for dimming controll for the artificial lighting.
Sensors are placed at a hights of 0.75 m above the floor and relatively central in each room.
Sensors are the blue dots and are used in Common rooms, staff room, the office, hallways and the wardrobes.

ApacheHVAC in IES<VE>

Common room:	($139m^3$ * $3h^{-1}$) / 3.6 ((l/s)/(s/h)) ~	116 l/s
(Three common rooms:	116 l/s *3 rooms	348 l/s)
Kitchens:	($131m^3$ * $4h^{-1}$) /3.6 ((l/s)/(s/h)) ~	146 l/s
Office:	($36m^3$ * $3h^{-1}$) /3.6 ((l/s)/(s/h)) ~	30 l/s
Total:		524 l/s

Equipment kitchen

Stove:	1000 W
Refrigerator & freezer:	210 kWh/year / 8760 = 25 W
Oven:	500 W
Hood above the stove:	200 W
Dishwasher:	300 W
Other electricical equipment:	500 W
Total	2525 W
Power consumption per m^2:	2525 W / 50 m^2 = 50.5 W/m^2