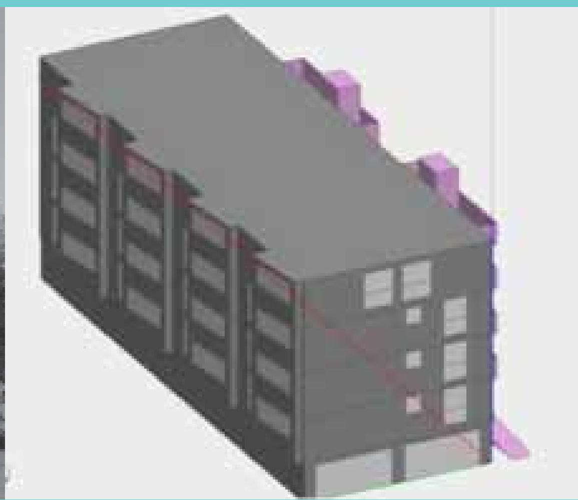
IEA ECBCS Annex 50
Prefabricated Systems for Low Energy
Renovation of Residential Buildings

Retrofit Simulation Report

March 2011


International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

IEA ECBCS Annex 50
Prefabricated Systems for Low Energy Renovation of Residential Buildings

Retrofit Simulation Report

March 2011

This report documents results of cooperative work performed under the IEA Program for Energy Conservation in Buildings and Community Systems, Annex 50 “Prefabricated Systems for Low Energy Renovation of Residential Buildings”

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Retrofit Simulation Report

IEA - International Energy Agency
ECBCS - Energy Conservation in Buildings and Community Systems
Annex 50 – Prefabricated Systems for Low Energy Renovation of Residential Buildings

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http://www.ecbcs.org

Empa - Swiss Federal Laboratories for Materials Science and Technology, March 2011

Preface

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster co-operation among the twenty-eight IEA participating countries and to increase energy security through energy conservation, development of alternative energy sources and energy research, development and demonstration (RD&D).

Energy Conservation in Buildings and Community Systems

The IEA co-ordinates research and development in a number of areas related to energy. The mission of one of those areas, the ECBCS - Energy Conservation for Building and Community Systems Programme, is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research.

The research and development strategies of the ECBCS Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Building Forum Think Tank Workshop, held in March 2007. The R&D strategies represent a collective input of the Executive Committee members to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy conservation technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in three focus areas of R&D activities:

- Dissemination
- Decision-making
- Building products and systems

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but also identifies new areas where collaborative effort may be beneficial. To date the following projects have been initiated by the executive committee on Energy Conservation in Buildings and Community Systems (completed projects are identified by *):

Annex 1: Load Energy Determination of Buildings*
Annex 2: Ekistics and Advanced Community Energy Systems*
Annex 3: Energy Conservation in Residential Buildings*
Annex 4: Glasgow Commercial Building Monitoring*
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities*
Annex 7: Local Government Energy Planning*
Annex 8: Inhabitants Behaviour with Regard to Ventilation*
Annex 9: Minimum Ventilation Rates*
Annex 10: Building HVAC System Simulation*
Annex 11: Energy Auditing*
Annex 12: Windows and Fenestration*
Annex 13: Energy Management in Hospitals*
Annex 14: Condensation and Energy*
Annex 15: Energy Efficiency in Schools*
Annex 16: BEMS 1- User Interfaces and System Integration*
Annex 17: BEMS 2- Evaluation and Emulation Techniques*
Annex 18: Demand Controlled Ventilation Systems*
Annex 19: Low Slope Roof Systems*
Annex 20: Air Flow Patterns within Buildings*
Annex 21: Thermal Modelling*
Annex 22: Energy Efficient Communities*

Annex 23: Multi Zone Air Flow Modelling (COMIS)*
Annex 24: Heat, Air and Moisture Transfer in Envelopes*
Annex 25: Real time HEVAC Simulation*
Annex 26: Energy Efficient Ventilation of Large Enclosures*
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems*
Annex 28: Low Energy Cooling Systems*
Annex 29: Daylight in Buildings*
Annex 30: Bringing Simulation to Application*
Annex 31: Energy-Related Environmental Impact of Buildings*
Annex 32: Integral Building Envelope Performance Assessment*
Annex 33: Advanced Local Energy Planning*
Annex 34: Computer-Aided Evaluation of HVAC System Performance*
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT)*
Annex 36: Retrofitting of Educational Buildings*
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx)*
Annex 38: Solar Sustainable Housing*
Annex 39: High Performance Insulation Systems*
Annex 40: Building Commissioning to Improve Energy Performance*
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG)*
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM)*
Annex 43: Testing and Validation of Building Energy Simulation Tools*
Annex 44: Integrating Environmentally Responsive Elements in Buildings*
Annex 45: Energy Efficient Electric Lighting for Buildings*
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)*
Annex 47: Cost Effective Commissioning of Existing and Low Energy Buildings*
Annex 48: Heat Pumping and Reversible Air Conditioning*
Annex 49: Low Exergy Systems for High Performance Buildings and Communities*
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings*
Annex 51: Energy Efficient Communities
Annex 52: Towards Net Zero Energy Solar Buildings
Annex 53: Total Energy Use in Buildings: Analysis & Evaluation Methods
Annex 54: Analysis of Micro-Generation & Related Energy Technologies in Buildings
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO)
Annex 56: Energy and Greenhouse Optimised Building Renovation

Working Group - Energy Efficiency in Educational Buildings*
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings*
Working Group - Annex 36 Extension: The Energy Concept Adviser*
Working Group - Energy Efficient Communities

* completed

Annex 50 "Prefabricated Systems for Low Energy Renovation of Residential Buildings"

Energy conservation is largely dominated by existing buildings. In most industrialized countries new buildings will only contribute 10% - 20% additional energy consumption by 2050 whereas more than 80% will be influenced by the existing building stock. If building renovation continues at the current rate and with the present common policy, between one to over four centuries will be necessary to improve the building stock to the energy level of current new construction.

Currently, most present building renovations address isolated building components, such as roofs, façades or heating systems. This often results in inefficient and in the end expensive solutions, without an appropriate long term energy reduction. Optimal results can not be achieved by single renovation measures and new problems could arise, including local condensation or overheating.

The objectives of this Annex have been the development and demonstration of an innovative whole building renovation concept for typical apartment buildings. The concept is based on largely standardised façade and roof systems that are suitable for prefabrication. The highly insulated new building envelope includes the integration of a ventilation system.

The concept is focused on typical apartment buildings that represent approximately 40% of the European dwelling stock. The advantages include:

- Achieving energy efficiency and comfort for existing apartment buildings comparable to new advanced low energy buildings i.e. 30-50 kWh/(m²·y);
- Optimised constructions and quality and cost efficiency due to prefabrication;
- Opportunity to create attractive new living space in the prefabricated attic space and by incooperating existing balconies into the living space;
- A quick renewal process with minimised disturbances for the inhabitants.

The deliverables of the project are:

Retrofit Strategies Design Guide

A building retrofit strategies guide [II] documenting typical solutions for whole building renovations, including prefabricated roofs with integrated HVAC components and for advanced façade renovation. The report is supplemented by the **Retrofit Simulation Report** [IX] and an electronic **'Retrofit Advisor'** [V] that allows a computer-based evaluation of suitable renovation strategies.

Retrofit Module Design Guide

Guidelines for system evaluation, design, construction process and quality assurance for prefabricated renovation modules [III]. This publication includes the technical documentation of all developed renovation solutions.

Case Study Building Renovations

Case studies of seven demonstration buildings in Austria, Netherlands, Sweden and Switzerland [IV].

Technical Summary Report

A summary report for a broad audience, demonstrating the potential of prefabricated retrofit [I].

Additional publications are:

- Annex 50 Fact Sheet, offering a short overview of the project and its achievements
- Building Typology and Morphology of Swiss and French Multi-Family Homes [VI], [VII], [VIII]

Home Pages: www.empa-ren.ch/A50.htm, www.ecbcs.org/annexes/annex50.htm

Participating Countries: Austria, Czech Republic, France, Netherlands, Portugal, Sweden, Switzerland

Retrofit Simulation Report

Summary

The goal of the calculation exercise was to show the order of magnitude of the measures to be taken with an example retrofit building at different locations in order to reach the energy demand goal of 30 to 50 kWh/a per m^2 gross heated area of primary energy for heating, ventilation and domestic hot water production. The measures to be taken include:

- Improved building insulation, including window replacements and additional insulation of opaque surfaces
- Application of a ventilation system with heat recovery
- Use of renewable energy sources, especially solar energy for domestic hot water production
- Improved energy production (by replacement of the heat generation), possibly including electricity production

The Swiss potential demonstration building "Elfenau", located in Lucerne, was chosen as the example building, being considered as typical enough for all participant countries. The building is one half of a multi-family house with three regular floors with 2 flats each, an unheated basement with garages, cellar rooms and a heating central, and an attic floor with two small single room flats and unheated attic space. The construction is rendered double brick masonry with concrete floor slabs and a concrete basement. The sloped roof is tile covered. Windows are double glazed with a wood frame. The radiator heating system is served by an oil fired boiler, which also provides domestic hot water. Ventilation is purely natural through open windows.

A three step procedure was applied to involve the different project partners with different calculation tools in the exercise:

- In a first step, the building was calculated "as is" at its original location, in order to compare the results achieved by the different partners with different tools. 4 partners (Belgium, Czech Republic, Portugal and Switzerland) with 5 different tools, 3 simplified tools (PEB - CALE2, RCCTE) and 3 detailed simulation programs (Bsim 2000, Energy+ and IDA-ICE 4.0), participated.
- In a second step, the same building was calculated at a location of the participant's country, in order to show the influence of the location on the same building. The same 5 participants performed these calculations with the same tools.
- In the third step, the building, retrofitted according to the strategy defined by the Swiss national retrofit team, had to be calculated at the location of the participant, and the respective measures had to be defined and quantified. Two partners (Portugal and Switzerland) with 3 tools (RCCTE, Energy+ and IDA-ICE 4.0) participated. The Swiss participant also ran simulations for the northern climate of Stockholm.

The step 1 calculations showed a systematic difference between the results for the useful energy demand for space heating (without domestic hot water) from the simplified calculation tools (137-147 kWh/(m²·y)) and from the detailed simulation programs (94-105 kWh/(m²·y)). By an additional calculation with a detailed simulation tool (IDA-ICE) it could be confirmed that this difference originates to a large extent by the different treatment of losses through or against unheated spaces like staircases, basements and unheated attic spaces. The accordingly simplified model lead to a value of 136 kWh/(m²·y). This also showed that there is a considerable reserve in the energy demand calculated by the simplified calculations for the buildings considered here due to the fact mentioned above.

From the step 2 calculations it could be seen that the energy demand of the building reacts as expected to the different climates for the locations considered (slightly lower heating demand in Liège, Belgium, slightly higher heating demand in Brno, Czech republic and considerably lower heating demand and a potential for cooling, if the respective measures are not taken, for the Portuguese location of Guimarães).

For the step 3 calculations, being the main step of this study, a retrofit strategy developed by the Swiss team was applied, which includes an extension of the heated space in the attic and basement floors, the enclosure of the balconies and an additional elevator tower with access balconies. The result of this step

show to the necessary building modifications to be applied at the different locations in order to reach the goal of a primary energy consumption for heating, ventilation and domestic hot water consumption of 30 to 50 kWh/(m²·y). According to the specifications, a mechanical ventilation system with an annual heat recovery efficiency of 0.8 had to be considered.

For the three climates of Lucerne, Stockholm and Guimarães, the measures (U-values) to reach the goal of 30 kWh/(m²·y) were identified as:

		Lucerne	Stockholm	Guimarães
Exterior walls – new parts - retrofitted existing walls	W/(m²·K)	0.15 0.2	0.15 <0.1*	0.23 0.23
Basement interior walls to non-heated zone	W/(m²·K)	0.55	0.55	0.73
Balcony floor	W/(m²·K)	0.15	0.15	0.67
Interior roof in contact with attic non-heated zone	W/(m²·K)	0.55	0.55	0.34
Window frame	W/(m²·K)	1.60	1.60	1.50
Glazing, U-value g-value	W/(m²·K) -	0.8 0.5	0.8 0.5	1.1 0.45
Collector area	m²	22.7	22.7	19.8

*or a different set of measures

And for 50 kWh/(m²·y)

		Lucerne	Stockholm	Guimarães
Exterior walls – new parts - retrofitted existing walls	W/(m²·K)	0.15 0.4	0.15 0.2	0.44 0.44
Basement interior walls to non-heated zone	W/(m²·K)	0.55	0.55	2.43
Balcony floor	W/(m²·K)	0.15	0.15	0.67
Interior roof in contact with attic non-heated zone	W/(m²·K)	0.55	0.55	0.50
Window frame	W/(m²·K)	1.60	1.60	2.35
Glazing, U-value g-value	W/(m²·K) -	0.8 0.5	0.8 0.5	2.1 0.45
Collector area	m²	22.7	22.7	15.84

For the Swiss climate – assuming that the elements added new to the building such as balcony enclosures, new elements in the attic floor and the roof are made according to Swiss 2010 standard target quality, i.e. having a U-Value of 0.15 W/(m²·K) – the value of 50 kWh/(m²·K) is not really a challenge. To reach the value of 30 kWh/(m²·y), measures were identified in dependence of the heat generation system. While the CHP according to the specifications and a gas boiler lead to nearly equal results given in the table above, the use of a heat pump allows for U-values for the existing building elements of 0.4 W/(m²·K), the limit being defined by the comfort and damage prevention requirements rather than by the energy target.

For the northern climate of Stockholm, the same measures are sufficient to get under the value of 50 kWh/(m²·y). To reach 30 kWh/(m²·y), considerably lower U-values would be needed in all parts.

Table of Content

1. Goal

The goal of the calculation exercise was, to show the order of magnitude of the measures to be taken at different locations in the countries represented in the task on typical retrofit cases, in order to reach the energy demand goal defined in the project definition, i.e. the amount of 30 to 50 kWh/(m²·y) of primary energy for heating, ventilation domestic hot water production and possibly cooling (if needed). With one or more example retrofit buildings, the measures to be taken to reach this goal should be specified and quantified. Measures include:

- Improved building insulation, including window replacements and additional insulation of opaque surfaces
- Application of a ventilation system with heat recovery
- Use of renewable energy sources, especially solar energy for domestic hot water production
- Improved energy production (by replacement of the heat generation), possibly including electricity production

The definition and quantification of the measures should be expressed in terms of:

- U-values to be achieved and – derived from this - thickness of additional insulation to be applied
- Specification of window properties to be applied
- Heat recovery efficiency requirements
- Contribution of active solar energy production to the domestic hot water production, and derived from this, area of collectors needed for this
- Specification of efficiency for heat and possibly electricity production

From this list, it can easily be seen, that a coincident optimisation of all these measures would be a multi dimensional optimisation procedure. This would have exceeded the possibilities of the project. Therefore, some of these measures could be assumed as fixed and used as boundary conditions for the ones to be determined.

2. Procedure

2.1. Object choice

2.1.1. Requirements

One or more example buildings had to be chosen for the calculations to be performed at. The requirements for these objects were the following:

- Representative for the different locations to be considered: the object had to be typical for locations from northern countries like Sweden and Denmark through central European like Czech Republic, France, Germany and Switzerland up to Mediterranean locations in Portugal
- Conformity with the target group of buildings of the project: the object had to be of the type of building (multi-family residential building representing a big portion of the stock and showing a typical retrofit case)

2.1.2. Choice

As a first object, a building had to be chosen, the documentation of which was available at the early stage of the project. Among the potential demonstration objects considered in Switzerland, the "Elfenau" building located in Lucerne was in a stage, where the existing building was well known and where some architectural retrofit studies had been made, which could be used as a base for the retrofit calculations.

The building, erected 1958 (see Figure 1, specifications in Appendix A and plans in Appendix B), was considered by all project group members representative for a considerable part of their building stock. Therefore it was decided to use this building as a first example to perform the calculations on.

Figure 1: Main façades of the Elfenau building (photos: Robert Fischer, HSLU)

2.2. Calculation procedure

2.2.1. Calculation steps

The calculations were performed in different steps as summarised in Table 1.

Calculation step	Description	Location	Climate	Building use
1	Building as is	Lucerne, Switzerland	Lucerne	According to specifications
2	Building as is	Chosen by contributing country	According to location	According to common practise in contributing country
3	Retrofit case	As for step 2	As for step 2	As for step 2

Table 1: Calculation steps

2.2.2. Overview of the calculations performed

For the different steps, different project partners contributed results, using different programs. Both simplified calculation tools (on a monthly or even seasonal basis) and detailed simulation programs were used. An overview of the contributions is given in Table 2.

Calculation step	Contributing country	Author	Tool	Tool category
1 and 2	Belgium	Descamps	PEB - CALE2 **Fehler! Verweisquelle konnte nicht gefunden werden.**	Simplified
	Portugal	Silva	RCCTE [2]	Simplified
	Portugal	Silva	Energy+ [3]	Detailed
	Czech republic	Sikula	Bsim 2000 [4]	Detailed
	Switzerland	Moosberger	IDA-ICE 4.0 [5]	Detailed
3	Portugal	Silva	RCCTE	Simplified
	Portugal	Silva	Energy+	Detailed
	Switzerland	Moosberger	IDA-ICE 4.0	Detailed

Table 2: Calculation contributions

Detailed calculations are room or room group based simulations with a time step of 1 h or less, whereas simplified calculations are monthly or seasonally based and generally treat the building as a whole.

2.2.3. Step 1 calculations

The goal of step 1 was, to compare the results from the different tools used by the different countries, in order to get an indication of the accuracy of the results obtained. The use of different level tools led to the expectation, that there would be differences in the results, which would have to be explained.

The calculations were performed based on the following information made available to the contributors:

- Specification document (Appendix A)
- A set of plans of the building, including situation, floor plans of all floors, façade views and cross sections (Appendix B)
- A set of photographs of the building (source: Robert Fischer, HSLU – T&A, not shown here)
- Climatic data for step 1 (Lucerne) in monthly and hourly resolution
- A set of primary energy factors for the evaluation of delivered energy carriers (see Appendix A)

The building use data were derived from the Swiss standard for heating energy performance of buildings (SIA 380/1 [6]). The global values for occupancy, lighting and equipment from this standard were translated into schedules, considering seasonal variations like day length for lighting etc., in order to provide enough detailed information for the detailed tools. This way it was made sure, that there was at least no difference between the detailed and simplified tools from this side.

The specifications also included "fuzzy" information on heat and water distribution and generation, to the contributors' interpretation. This information was unified later in the process, see chapter 3 below.

2.2.4. Step 2 calculations

In step 2, the influence of the different locations was to be shown. The calculations were made based on the same specification as step 1. Instead of the provided climate and use information, the contributor's own information was used.

2.2.5. Step 3 calculations

In step 3, the retrofit measures were applied, specified and quantified.

The base of this calculation was, in respect of building geometry, a retrofit strategy in form of a set of new plans, provided by the Swiss retrofit team (Appendix C).

This strategy considers the situation that retrofit measures often not only consist of an energy related improvement, but include building enhancements in form of additional space, added elements needed for compliance with current standards and regulations (not only energy, but security, handicapped accessibility etc.). The strategy, shown in Appendix C, includes an added lift tower and attached balconies, an extension of usable area in the attic and basement floors and the inclusion of former balconies in the heated area.

In addition to the retrofit strategy, a further specification document was handed out (Appendix D).

3. Results

3.1. Step 1 and 2 results

3.1.1. Reporting

Reports were received from all contributors, giving the required results and additional information on the calculations, like assumptions made and more detailed results. These can be found in appendices E, F and G. These reports are given in the format in which they were received from the contributors. Therefore the format is not the same for all, and a comparison is difficult. However, the different tools used by the contributors provide different output formats which sometimes cannot be changed, including even aspects like the language in some cases. The relevant numbers were extracted by the coordinator and summarised in the following paragraphs.

3.1.2. Step 1 results

The results from the different contributors for steps 1 and 2 are shown in Table 3 below.

For the primary energy, two columns are shown for both cases. The first columns contain the values provided by the contributor (labelled "reported"). Due to differences and inconsistencies in the interpretation of system aspects (distribution, generation) and primary energy calculations, these values are not comparable. Therefore a value is given in the second column (labelled "unified"), derived from the contributed values for the useful energy demands for space heating. The assumptions for the calculation of these values are: useful energy demand for domestic hot water: Q_w = 75 MJ/(m^2·y); distribution efficiency for domestic hot water: $\eta_{d,W}$ = 0.7; heat generation efficiency (heating and domestic hot water): η_g = 0.8; primary energy factor: f_{PE} = 1.24 (oil). With this, the following calculation formula results, and the values can directly be compared.

$$E_p = (Q_h + Q_W / \eta_{d,W}) / \eta_g \cdot f_{PE} = (Q_h + \frac{75}{36 \cdot 0.7}) / 0.8 \cdot 1.24$$

		Step 1: as is, Lucerne climate			Step 2: as is, local climate			
		Useful energy demand for space heating	Primary energy, reported	Primary energy, unified		Useful energy demand for space heating	Primary energy, reported	Primary energy, unified
Contributor	**Program**	kWh/m^2	kWh/m^2	kWh/m^2	Location	kWh/m^2	kWh/m^2	kWh/m^2
Descamps	PEB-CALE2	137	252	259	Liège	125	234	239
Silva	RCCTE	147	308	274	Guimarães	60	173	139
Silva	Energy+	98	222	198	Guimarães	18	98	74
Sikula	Bsim 2000	105		209	Brno	139		261
Moosberger	IDA-ICE 4.0	94	192	192	Lucerne			
Meier	IDA-ICE 4.0 with simplifications, see 3.1.1	136		257	Lucerne			

Table 3: Calculation results from steps 1 and 2

From Table 3 it can be seen that there is a variety in the resulting energy demand of +/- 20% in primary energy against the average value. In useful heating energy demand, the variety is even close to +/- 25%. This result is not a surprise, considering the different tool categories involved.

3.1.3. Step 1 results analysis

A systematic difference can be recognised between the results for the useful energy demand for space heating achieved with the simplified tools (values around 142 +/- 5 kWh/m²) and the detailed simulation programs (values around 100 +/- 6 kWh/m²). Therefore there must be reasons to be identified for these differences. From the coordinator's experience, the following areas of possible reasons were identified to be verified by the additional cases:

- Staircase:
  In simplified calculations, the unheated staircase is usually counted as a heated space, because it is within the insulation perimeter.
  In the detailed simulations it is treated as an unheated space, its temperature being calculated as a result of the heat flows, which is closer to reality.
- Unheated attic and unheated basement:
  In simplified calculations, the walls towards these rooms are calculated as against outdoor climate with a correction factor according to European standards („b-factor"). This is a simplification, and the given b-factors are overestimating the losses through these walls to be on the safe side.
  In the detailed simulations, these rooms are again more accurately treated as unheated spaces.

An additional round of simulations with the IDA-ICE program was performed by Stefan Meier (HSLU). A modified IDA-ICE input was created, with the simplifications according to the simplified tools listed above in place. The results are given in the bottom line of Table 3. The value of 136 kWh/(m^2·y) for the useful heating energy demand is about equal to the lower result of the simplified tools. Some further differences of minor importance may originate from other differences, e.g. in control.

This result confirms the coordinator's suspicion and shows, that there is a considerable reserve in the simplified tools due to "safe side" assumptions.

3.1.4. Step 2 results

The results for the Belgian location are quite similar to the original location results, slightly lower, which could be expected due to the slightly milder, more maritime and lower altitude climate. In Brno, the climate seems to be somewhat more severe, which could also be expected, regarding the more continental location and higher latitude.

For the Mediterranean Guimarães location, the heating energy demand is, as expected, considerably lower. Here the difference between the simplified and detailed calculation becomes even more important, the latter showing results even close to 0 for the useful heating energy demand. It has to be stated that the primary energy results for this case do not contain any cooling contribution, since existing buildings do not have the respective equipment although it might be needed from a thermal comfort perspective.

3.2. Step 3 results

Contributions for the step 3 calculations were received from two sources:

- Simulations with IDA-ICE 4.0 from HSLU (Sven Moosberger), for original Swiss location (Lucerne); these were complimented by a few calculations for a Nordic climate (Stockholm).
- Calculations with both a simplified tool (RCCTE) and a detailed simulation program (DesignBuilder -> Energy+) from University of Minho (Pedro Silva) for the Mediterranean location of Guimarães.

3.2.1. Results for Lucerne

In a first round, results were reported, the full report of which, including all simulation details and results, can be found in Appendix H. These results were considered too theoretic for the following reasons:

- Some of the glass U-values were too low (too expensive for retrofit case)
- Some of the opaque constructions are not in compliance with the Swiss standard on heat and humidity protection (too high U-values)
- New elements and existing construction have the same insulation quality, which is unrealistically poor for the new parts
- Some misinterpretation in respect of the combined heat and power generation was introduced

Therefore, a second round of simulations was performed based on the same input, considering these points. The details reported in Appendix H remain the same, except for the following boundary conditions which were observed in this round:

- Constant, high quality insulation level in elements added new to the building and in the roof (which is replaced anyway) according to the Swiss energy standard 2009 target value (U-value 0.15 W/(m²·K).
- Constant window and glazing quality according to Swiss voluntary Minergie® label (Uw = 1.0 W/(m²·K), g = 0.5).
- Varying only the insulation to be added on the existing walls. The insulation level must not exceed the limit from Swiss standard SIA 180 for heat and humidity protection [7] (U ≤ 0.4 W/(m²·K); this is not an energy related requirement, but to assure comfort and avoid damage).

The results from this second round are shown in Tables 4 to 6.

Construction	30 kWh/(m²·y)		50 kWh/(m²·y)	
	Insulation thickness cm	U-value W/(m²·K)	Insulation thickness cm	U-value W/(m²·K)
Exterior walls - new parts - retrofitted existing walls	23 – 24 15 – 18	0.15 0.20	23 – 24 6 – 9	0.15 0.40
Basement interior walls to non-heated zone	5	0.55	5	0.55
Balcony floor	23	0.15	23	0.15
Interior roof in contact with attic non-heated zone	5	0.55	5	0.55
Window frame	-	1.60	-	1.60
Glazing	-	0.80	-	0.80

Table 4: Construction Elements: U-Values for location Lucerne

30 kWh/(m²·y)	50 kWh/(m²·y)
0.5	0.5

Table 5: Glazing g-values for location Lucerne

The results reported above include the contribution from solar collectors for the domestic hot water production with the data according to Table 6.

Type of collector	30 kWh/(m²·y)			50 kWh/(m²·y)		
Exposition horizontal	Gross area m²	Absorber Area m²	Heat production kWh/(m²·y)	Gross area m²	Absorber area m²	Heat production kWh/(m²·y)
Vacuum tube	30	22.7	11.4	30	22.7	11.4

Table 6: Solar panels contribution for location Lucerne

Additionally, the heat generation type was varied, since the CHP foreseen in the project is rather unusual and the influence on the result is significant. A gas boiler and a heat pump with a seasonal performance factor of 3.4 (HP) were considered in parallel.

The results from these additional variations are shown in Table 7 and Figure 3 (including 1st round results).

The results from Figure 3 and Table 7 show, that the goal of 50 kWh/(m^2·y) is easily undercut by far with the boundary conditions considered. The goal of 30 kWh/(m^2·y) can be reached with different levels of insulation, depending on the heat generation type. With a gas boiler and the foreseen CHP system, the values are almost equal: wall insulations with U=0.2 W/(m^2·K) are sufficient. The CHP (assumed to be oil fired) compensates its worse primary energy factor with the generated electricity, which is accounted for in delivering part of the fan energy of the ventilation system. It has to be stated that the CHP has an additional benefit not reported in the numbers considered here: its produced electricity covers also a part of the consumption for lighting and equipment, in the order of magnitude of 12 to 16 kWh/(m^2·y) (depending on the insulation level, because the operation hours are different). With a heat pump, the goal is reached even with U = 0.4 W/(m^2·K).

Case	U-value existing walls	Insulation	Generation type	Primary energy
	W/(m^2·K)	cm		kWh/(m^2·y)
3.w	0.15	20 – 23	CHP	28.9
			Gas boiler	28.4
			HP	21.7
3.x	0.2	15 – 18	CHP	30.4
			Gas boiler	29.8
			HP	22.6
3.y	0.3	10 – 12	CHP	33.4
			Gas boiler	32.7
			HP	24.6
3.z	0.4	6 – 9	CHP	36.4
			Gas boiler	35.6
			HP	26.6

Table 7: 2nd round results (primary energy for heating, ventilation and domestic hot water) for different heat generation types

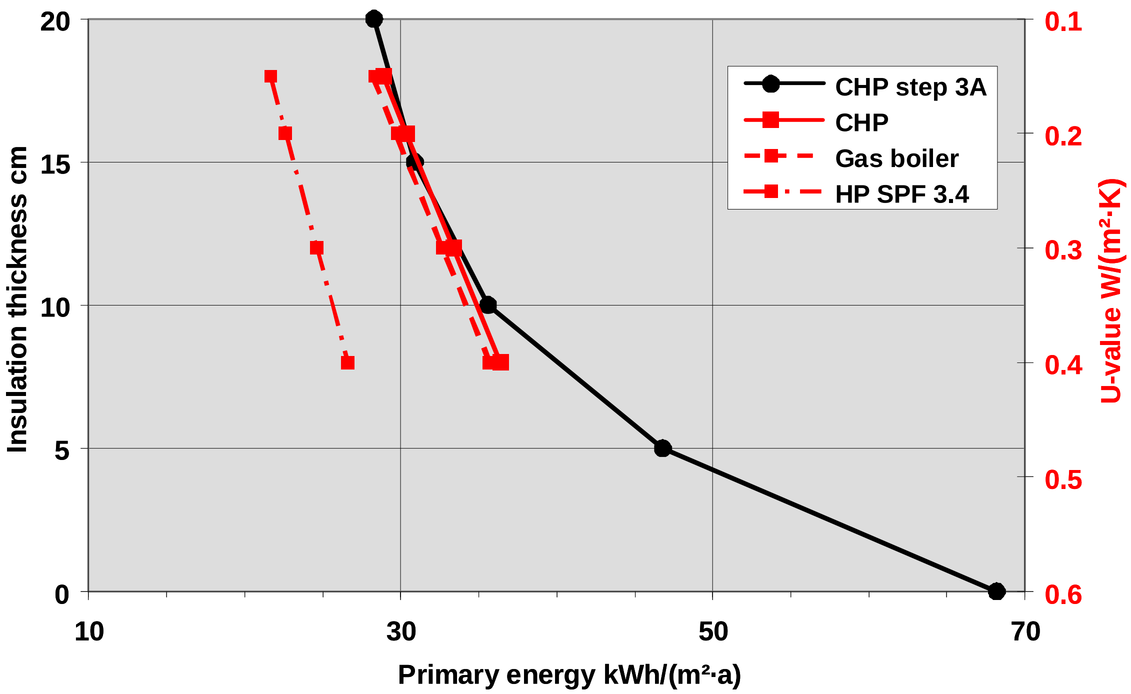

Figure 3: Results (primary energy for heating, ventilation and domestic hot water) for location Lucerne, 1st (blue) and 2nd round (pink), for different heat generation types

3.2.2. Results for Stockholm

With the same tool and input as for the Lucerne location, simulations were done also for the Nordic climate of Stockholm. Some differences originating from local standards or regulations were not considered. E.g. the ventilation rate would be required to be 0.5 ach (0.35 l/s·m²) rather than 0.3 ach. The contribution from the solar collectors was not changed and assumed to be the same, which is probably not true. This would, however, not influence the results dramatically and could be compensated by an increased collector area.

Case	U-value existing walls	Insulation	Generation type	Primary Energy
	W/(m²·K)	cm		kWh/(m²·y)
3.x SE	0.2	15 – 18	CHP	47.7
			Gas boiler	41.5
			HP	33.9

Table 8: Results (primary energy for heating, ventilation and domestic hot water) for Stockholm

From the results shown in Table 8 it can be seen, that with a U-value of 0.2 W/(m²·K), the primary energy value is within the boundaries of 30 to 50 kWh/(m²·y) for all types of generation. Looking at the slope of the curves in Figure 3, it must be concluded, however, that even with the heat pump a dramatic decrease of the U-values of the retrofitted existing walls below U = 0.1 W/(m²·K) would be needed to reach the target of 30 kWh/(m²·y). Other combinations of measures would be recommendable in that case (lower U-values also for new added elements and windows).

3.2.3. Results for Guimarães

The results for both the simplified and detailed calculations reported for this location are the same, shown in the following paragraphs. The associated energy consumption values are slightly different, but for both cases in the order of the target. They can be found in Appendix I.

The simplified calculation applied delivers also an energy demand for cooling. This portion was not counted in the primary energy reported. If this would be integrated, the associated primary energy would be equal to the useful energy – the annual efficiency factor for the generation of 3 (according to

Portuguese building regulations) being equal to the primary energy factor assumed in this study of 2.97. The total primary energy would in this case be slightly over the target, and some compensation would have to be applied.

Construction	30 kWh/(m²·y)		50 kWh/(m²·y)	
	Insulation thickness cm	U-value W/(m²·K)	Insulation thickness cm	U-value W/(m²·K)
Exterior walls	15.0	0.23	6.0	0.44
Basement interior walls to non-heated zone	4.0	0.73	0.0	2.43
Balcony floor	4.0	0.67	4.0	0.67
Interior roof in contact with attic non-heated zone	8.0	0.34	4.0	0.50
Window frame	-	1.50	-	2.35
Glazing (g-value 0.45)	-	1.10	-	2.10

Table 9: Construction Elements: U-Values for Guimarães

Type of collector	30 kWh/(m²·y)		50 kWh/(m²·y)	
	Area m²	Heat production kWh/(m²·y)*	Area m²	Heat production kWh/(m²·y)*
Compound Parabolic Concentrating Collector (CPC)	19.80	12.27	15.84	10.22

* for whole building

Table 11: Solar Panels Contribution for Guimarães

4. Summary and Conclusions

The step 1 calculations have shown that

- There is a systematic difference between the simplified and detailed calculation methods, which leads to 42% higher values for the useful energy demand for space heating given by the simplified tools. This can be explained to a large extent by the different treatment of losses through or against unheated spaces like staircases, basements and unheated attic spaces.
- There is a considerable reserve in the energy demand calculated by the simplified calculations for the buildings considered here due to the fact mentioned above.

From these results, it must be concluded that

- Care must be taken when applying different classes of tools for the same target. The boundary conditions, including simplified assumptions for e.g. the treatment of unheated spaces, must be carefully set and clearly stated to ensure comparable results.
- The class of tool to be applied have to be considered and the assumptions to be made must be clearly defined when defining targets, e.g. in building regulations and standards.

From the step 2 calculations it could be seen that the energy demand of the building reacts as expected to the different climates for the locations considered:

- Slightly lower heating demand in Liège (Belgium)
- Slightly higher heating demand in Brno (Czech republic)

- Considerably lower heating demand and a potential for cooling, if the respective measures are not taken, for the Mediterranean location of Guimarães (Portugal)

The step 3 calculations, being the main step of this study, lead to the necessary building modifications to be applied at the different locations in order to reach the goal of a primary energy consumption for heating, ventilation and domestic hot water consumption of 30 to 50 kWh/(m^2·K).

For the three climates of Lucerne, Stockholm and Guimarães, the measures (U-values) to reach the goal of 30 kWh/(m^2·y) or 50 kWh/(m^2·y) were identified as shown in Table 12.

		Lucerne	Stockholm	Guimarães
Exterior walls – new parts - retrofitted existing walls	W/(m^2·K)	0.15 0.20	0.15 <0.1*	0.23 0.23
Basement interior walls to non-heated zone	W/(m^2·K)	0.55	0.55	0.73
Balcony floor	W/(m^2·K)	0.15	0.15	0.67
Interior roof in contact with attic non-heated zone	W/(m^2·K)	0.55	0.55	0.34
Window frame	W/(m^2·K)	1.60	1.60	1.50
Glazing, U-value g-value	W/(m^2·K) -	0.80 0.50	0.80 0.50	1.10 0.45
Collector area	m^2	22.7	22.7	19.8

*or a different set of measures

Table 12: Measures required in order to reach an energy consumption of 30 kWh/(m^2·y)

		Lucerne	Stockholm	Guimarães
Exterior walls – new parts - retrofitted existing walls	W/(m^2·K)	0.15 0.40	0.15 0.20	0.44 0.44
Basement interior walls to non-heated zone	W/(m^2·K)	0.55	0.55	2.43
Balcony floor	W/(m^2·K)	0.15	0.15	0.67
Interior roof in contact with attic non-heated zone	W/(m^2·K)	0.55	0.55	0.50
Window frame	W/(m^2·K)	1.60	1.60	2.35
Glazing, U-value g-value	W/(m^2·K) -	0.80 0.50	0.80 0.50	2.10 0.45
Collector area	m^2	22.7	22.7	15.84

Table 13: Measures required in order to reach an energy consumption of 50 kWh/(m^2·y)

For the Swiss climate – assuming that the elements added new to the building such as balcony enclosures, new elements in the attic floor and the roof are made according to Swiss 2010 standard target quality, i.e. having a U-Value of 0.15 W/(m^2·K) – the value of 50 kWh/(m^2·K) is not really a challenge. To reach the value of 30 kWh/(m^2·y), measures were identified in dependence of the heat generation system. While the CHP according to the specifications and a gas boiler lead to nearly equal results given in the Table above, the use of a heat pump allows for U-values for the existing building elements of 0.4 W/(m^2·K), the limit being defined by the comfort and damage prevention requirements rather than by the energy target.

For the northern climate of Stockholm, the same measures are sufficient to get under the value of 50 kWh/(m^2·y). To reach 30 kWh/(m^2·y), considerably lower U-values would be needed in all parts.

The results show that the given span of the goal of 30 to 50 kWh/(m^2·y) is quite large. The upper boundary not really being a challenge, except for the northern climate, the measures identified for the lower are reasonably to achieve – for the Swiss climate even with surprisingly high U-values.

From these results it can be concluded that

- Setting targets on the level of primary energy for space heating, ventilation and domestic hot water leads to a strong dependency on the type of heat generation. It must be decided whether this higher degree of freedom is wanted.
- It is possible with a reasonable technical effort to achieve a target of 30 kWh/(m²·y) for a wide range of European climates.

5. References

Publications within the IEA ECBCS Annex 50[1]:

[I] Mark Zimmermann: ECBCS Project Summary report "Annex 50 Prefabricated Systems for Low Energy Renovation of Residential Buildings, March 2011

[II] Peter Schwehr, Robert Fischer, Sonja Geier: Retrofit Strategies Design Guide, ISBN 978-3-905594-59-1, March 2011

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[VII] Bertrand Ruot: French housing stock built between 1949 and 1974, October 2010

[VIII] Bertrand Ruot: Elements of morphology of collective housing buildings constructed in France between 1949 and 1974, October 2010

[IX] Gerhard Zweifel: Retrofit Simulation Report, March 2011

Further literature:

[1] PEB - CALE2: Belgian calculation tool for energy certification based on EN ISO 13790; http://energie.wallonie.be/fr/outil-de-calcul-ew-pour-les-logements-neufs-cale-version-2-0-valable-jusqu-au-31-decembre-2009.html?IDC=6094&IDD=11074

[2] RCCTE: Portuguese calculation tool for energy certification based on EN ISO 13790; www.rccte.com

[3] Energy+: US Department of Energy Simulation Software; http://apps1.eere.energy.gov/buildings/energyplus/

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[5] IDA-ICE 4.0: Equa Simulation AB, Solna, Sweden; www.equa.se

[6] Standard SIA 380/1 "Thermische Energie im Hochbau"; Swiss Association of Architects and Engineers, Zürich, 2009

[7] Standard SIA 180 „Wärme- und Feuchteschutz im Hochbau", Swiss Association of Architects and Engineers, Zürich, 1999

[8] SIA Merkblatt 2031: "Energieausweis für Gebäude"; Swiss Association of Architects and Engineers, Zürich, 2009

[1] Further information at home pages: www.empa-ren.ch/A50.htm, www.ecbcs.org/annexes/annex50.htm

Appendix A
Step 1 and 2 Specification

1. Location, situation and building part to be considered

1.1. Geographic location:

Longitude: 8°19' east
Latitude: 47°02' north
Altitude: 477 m above sea level

1.2. Climatic data

The data provided are from the new SIA climatic data collection for the station Lucerne; geographic data:

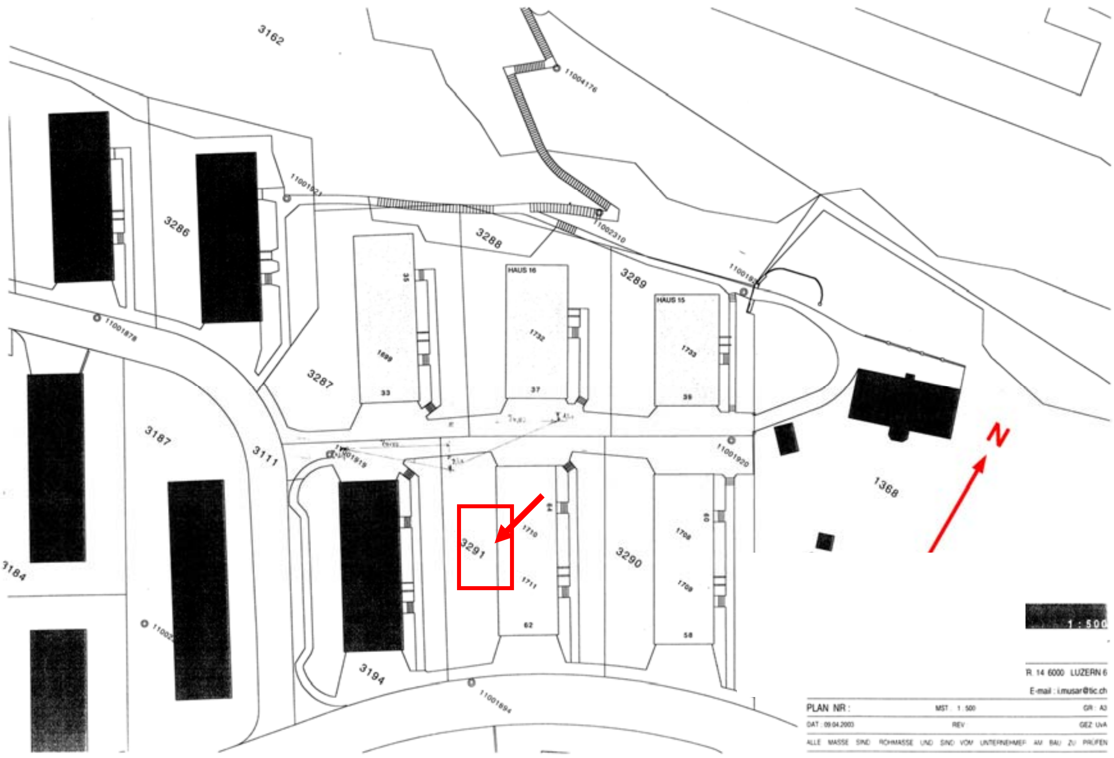
Longitude: 8°18' east
Latitude: 47°02' north
Altitude: 456 m above sea level

For monthly/seasonal calculations: see file Lucerne_monthly.xls; if you need other data like degree-days, please generate from hourly data.

For hourly calculations: see file lucerne_hourly.xls; this file contents a lot of parameters which are identified in the column headings. You should be able to choose the appropriate ones for your software, and EXCEL allows generating data formats like txt or csv. Otherwise contact me.

1.3. Situation

The building is situated as follows:



The neighbour building in south-west direction (left on situation plan above) is of the same height and is situated on the same level as the building considered. The building in north-east direction is situated 1.3 m lower, but also of the same height. Buildings south-east are of big enough distance and lower altitudes to be neglected.

2. Building

2.1. General

Building gross heated area: 565 m^2
Net used area (staircase excluded): 452 m^2
Single room areas can be taken from floor plans.

2.2. Geometry

The building geometry can be taken from the plans enclosed as jpg-Files.

2.2.1. Legend for room names

Wohnzimmer	living room
Zimmer	bedroom
Küche	kitchen
Bad	bathroom
Vorplatz	corridor
Estrich	unheated attic space

2.2.2. Basement

Although in reality there is a central heating room in the basement of our unit, we neglect this and consider the whole basement as unheated cellar, also the garages. The south-west wall of the basement is fully in the ground, the north-east side is half to the outside air.

2.2.3. Window sizes

The sizes of the windows without dimensions in the plans are:

Living room south-west:
Width: 1.95 m Height: 1.32 m

Bedrooms north-east and south-east:
Width: 1.25 m Height: 1.32 m

Bathrooms north-east and south-east:
Width: 1.0 m Height: 1.0 m

Skylights in attic kitchens and bathrooms:
Width: 0.6 m Height: 0.6 m

2.3. Constructions

2.3.1. Exterior walls

All construction layers are given from inside to outside and from top to bottom (for inside ceilings).

Exterior walls 30 cm

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m^3	J / (kg·K)
Plaster finish	1	0.7	1400	1000
Brick masonry	30	0.47	1200	940
Mineral render	1.5	0.87	1800	1000

Exterior walls balcony 25 cm

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m^3	J / (kg·K)
Plaster finish	1	0.7	1400	1000
Brick masonry	12	0.47	1200	940
Cavity	3	0.11*		
Brick masonry	10	0.47	1200	940
Exterior rendering	1.5	0.87	1800	1000

Exterior walls balcony north-east (small strip next to balcony door in kitchens)

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Plaster finish	1	0.7	1400	1000
Brick masonry	6	0.47	1200	940
Cavity	3	0.11*		
Brick masonry	6	0.47	1200	940
Exterior rendering	1.5	0.87	1800	1000

*EN 6946

Exterior walls 12 cm balustrade, below windows, behind radiators (cross section incorrect)

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Plaster finish	1	0.7	1400	1000
Brick masonry	12	0.47	1200	940
Mineral render	1.5	0.87	1800	1000

Exterior walls basement

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Reinforced concrete	30	1.35	2400	1000

2.3.2. Windows and doors

All windows and balcony doors except skylights are double glazed with air filling (no gas) and no coating (2 clear glasses). Wood frames with an average glass portion of PP %.

They have rolling shutters for shading all around (except basement windows)

Ordinary windows

U_g	U_f	Glass portion	g	g_{shaded}
W / (m²·K)	W / (m²·K)	-	-	-
2.9	1.4	0.75	0.77	0.13

Skylights in attic apartment

Metal frame with single glazing.

U_g	U_f	Glass portion	g
W / (m²·K)	W / (m²·K)	-	-
5.0	4.0	0.8	0.85

Main door

Metal frame with single glazing.

U_g	U_f	Glass portion	g
W / (m²·K)	W / (m²·K)	-	-
5.0	4.0	0.68	0.85

Garage doors, basement

Material	Thickness	Conductivity	Density	Specific heat
	Cm	W / (m·K)	kg / m³	J / (kg·K)
Fir wood	4	0.13	500	1600

2.3.3. Roofs

Roof above heated attic apartment rooms

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Roof tiles	5	1.0	2000	800
Cavity	12+	018		
Mineral wool	4	0.055	60	1030
Fir wood	1.5	0.13	500	1600

Roof above unheated attic space

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Roof tiles	5	1.0	2000	800

2.3.4. Interior ceiling (all floors except wet rooms)

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Wood parquet	2	0.18	700	1600
Cast cement floor	8	0.87	1800	1000
Reinforced con-crete	30	1.35	2400	1000
Plaster finish*	1	0.7	1400	1000

* except basement

2.3.5. Interior ceiling (kitchens and bathrooms)

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Ceramic tiling	2	1.3	2300	840
Cast cement floor	8	0.87	1800	1000
Reinforced con-crete	30	1.35	2400	1000
Plaster finish*	1	0.7	1400	1000

* except basement

2.3.6. Interior walls

Interior walls 15 cm

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Plaster finish	1	0.7	1400	1000
Brick masonry	12	0.47	1200	940
Plaster finish	1	0.7	1400	1000

Interior walls 6 cm

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Plaster finish	1	0.7	1400	1000
Brick masonry	6	0.47	1200	940
Plaster finish	1	0.7	1400	1000

Interior apartment separation wall

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Plaster finish	1	0.7	1400	1000
Brick masonry	12	0.47	1200	940
Cavity	3	0.11*	1400	1000
Brick masonry	5	0.47	1200	940
Plaster finish	1	0.7	1400	1000

Firewall to neighbour building

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Plaster finish	1	0.7	1400	1000
Brick masonry	12	0.47	1200	940
Cavity	2	0.11*	1400	1000
Brick masonry	12	0.47	1200	940
Plaster finish	1	0.7	1400	1000

Attic apartment interior walls

All walls are brick masonry with plaster finish, values as above. Please take thicknesses from floor plan.

Basement central interior wall

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Reinforced concrete	25	1.35	2400	1000

Basement interior separation walls

Material	Thickness	Conductivity	Density	Specific heat
	cm	W / (m·K)	kg / m³	J / (kg·K)
Cement brick masonry	15	1.1	2000	900

Neglect all thinner separation walls.

2.3.7. Thermal bridges

Wall / ceiling joint

All concrete ceilings penetrate completely the exterior walls and are only covered by the mineral render layer.

Balconies

The ceilings are lead through and form the balconies, no thermal separation. But in the balcony area they are thinner or tapered, respectively.

Window-wall connection

All windows are fixed on the inside of the outer brick layer or to an edge brick of 12 cm depth.

Roller blind cases

Above all windows there is a case for the roller blinds, up to the ceiling and over the whole window width. Inside cover is a 2 cm wood board, outside there is a 6 cm brick layer, but the cases are not closed from the bottom.

2.3.8. Air tightness, infiltration and ventilation

An air exchange rate of 0.3 h^{-1} shall be applied for the untightness of the building shell.

The hygienic ventilation rate is 30 m^3/(h·person) at daytime and 15 m^3/(h·person) at night time, but when the above untightness value is bigger, this shall be applied.

There are no mechanical ventilation systems (cooking hoods neglected).

3. Building Use

3.1. Occupation

Occupation density: 32 m^2 net area/person (also if uneven person numbers result)

Metabolic rate: 1.2 met

Heat emission 70 W/person (sensible)

Humidity emission 80 g/h person

Average presence time per day (for monthly/seasonal calculations): 12 h

Daily schedule (for hourly calculations):

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Value	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.6	0.4	0.4	0.4	0.6	0.8	0.6	0.4	0.4	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0

Monthly schedule (for weighting the daily profile above):

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Value	0.7	0.5	0.9	0.7	0.5	0.9	0.4	0.4	0.9	0.7	0.9	0.5

3.2. Electric equipment

Nominal power: 3.0 W/m^2

Average operation hour per day (for monthly/seasonal calculations): 9.3 h

Annual operation hours: 3400 h

Annual electric energy consumption: 10 kWh/m^2 net area

Annual electric energy consumption: 30 MJ/m^2 gross area

Daily schedule (for hourly calculations):

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Value	0.1	0.1	0.1	0.1	0.1	0.1	0.5	1.0	0.5	0.5	0.5	1.0	1.0	0.5	0.5	0.5	1.0	1.0	1.0	1.0	0.5	0.5	0.5	0.1

Monthly schedule (for weighting the daily profile above):

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Value	0.8	0.6	1.0	0.8	0.6	1.0	0.6	0.6	1.0	0.8	1.0	0.6

3.3. Lighting

Nominal power: 9.4 W/m^2

Average operation hour per day (for monthly/seasonal calculations): 7 h

Annual operation hours: 2550 h

Annual electric energy consumption: 24 kWh/m^2 net area

Annual electric energy consumption: 70 MJ/m^2 gross area

Daily schedules (for hourly calculations):

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0
Feb	0	0	0	0	0	0	1	1	0.5	0	0	0	0	0	0	0	0.5	1	1	1	1	1	1	0
Mar	0	0	0	0	0	0	1	0.5	0	0	0	0	0	0	0	0	0	0.5	1	1	1	1	1	0
Apr	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0.5	1	1	1	1	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
Aug	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0.5	1	1	1	1	0
Sep	0	0	0	0	0	0	1	0.5	0	0	0	0	0	0	0	0	0	0.5	1	1	1	1	1	0
Oct	0	0	0	0	0	0	1	1	0.5	0	0	0	0	0	0	0	0.5	1	1	1	1	1	1	0
Nov	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0
Dec	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0

3.4. Setpoints

Heating setpoint (from 06:00h to 22:00 h): 20°C

Night set back (from 22:00h to 06:00 h): through supply temperature set back, see heating system below.

4. Domestic hot water

4.1. Consumption

35 l/d person at a temperature level of 65°C; cold water entry 10°C.

Annual energy consumption: 75 MJ/m^2 gross area

4.2. Distribution

Annual efficiency: 0.7

4.3. Generation

Oil boiler for combined generation of heating and domestic hot water -> see HVAC systems.

5. Heating system

5.1. Distribution and emission

There are radiators with thermostatic valves below all windows in the apartment rooms. In bathrooms they are on the interior wall.

The design temperature level is 70/50 °C, and the temperature is outdoor-reset.

Supply temperature set back (from 22:00h to 06:00 h): -20 K

5.2. Generation

Oil boiler for combined generation of heating and domestic hot water.

Annual efficiency: 0.80

6. Cases to be calculated

Case 1: Building as described, with Swiss climate and building use as specified above in clauses 1 and 3 to 5

Case 2: Building as described, with one local climate of your country, chosen by yourself, and building use as specified according to your local standards and/or regulations.

7. Reporting

7.1. Useful heating energy demand

Useful energy demand for heating Q_h shall be reported in relation to the building gross heated area.

7.2. Delivered energy demand

The delivered energy (oil) for heating and DHW shall be reported in relation to the building gross heated area.

8. Primary energy factors

Extract from Swiss standard SIA MB 2031 [8] on energy certificate:

D.1 Dichte, Brennwerte, Primärenergiefaktoren gesamt, erneuerbarer Energieanteil und Treibhausgasemissionskoeffizienten

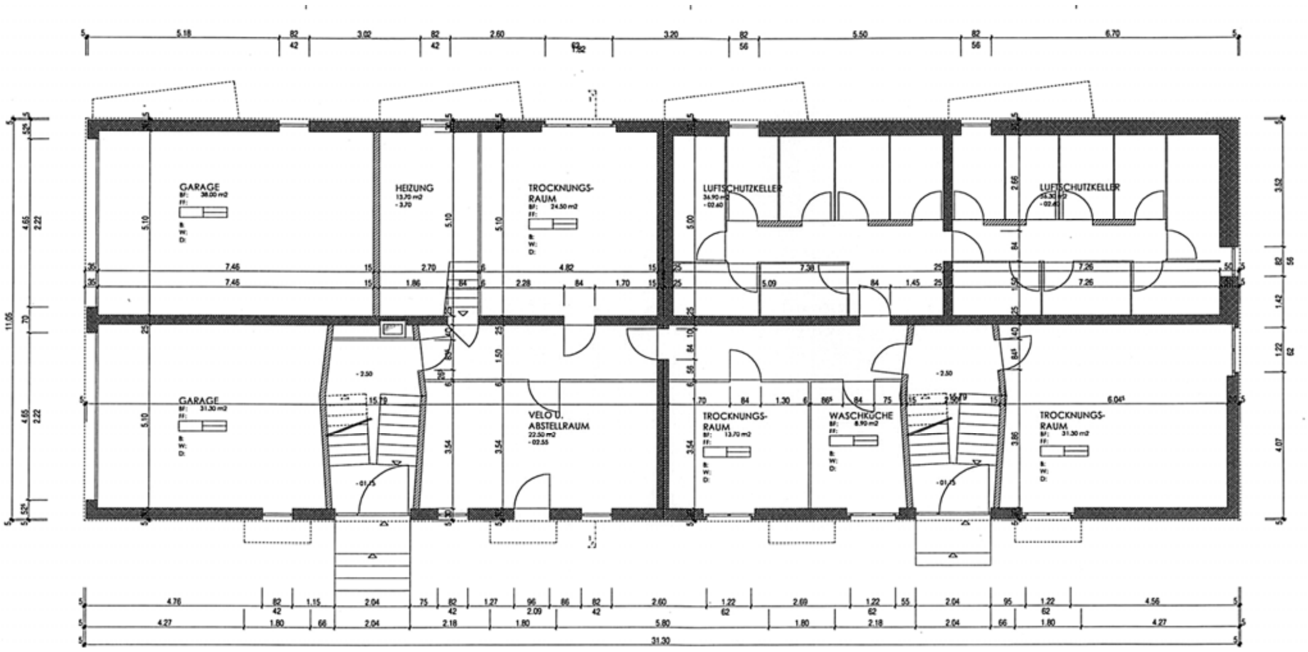
		Dichte	Brennwert (oberer Heizwert)	Primärenergiefaktor total	Erneuerbarer Primärenergieanteil	Treibhausgesemissionskoeffizient
Brennstoffe						kg CO_2 /MJ
flüssig		kg/m³	MJ/kg			
	Heizöl EL	840	44,8	1.24	0.7%	0.082
	Propan	510	50,0	1.15	0.5%	0.067
	Butan	580	49,5	1.15	0.5%	0.067
fest		kg/m³	MJ/kg			
	Kohle Koks		28,8	1.66	0.7%	0.120
	Kohle Brikett		21,2	1.19	0.6%	0.107
	Stückholz 1)	540 - 780	16,2 - 16,9	1.06	95.2%	0.003
	Holzschnitzel 1)	675 - 975	13,0 - 13,7	1.14	94.6%	0.003
	Pellets	1200	20,2	1.22	83.0%	0.010
gasformig 2)		kg/m³	MJ/m³			
	Erdgas	0,76	40,3	1.15	0.5%	0.067
	Propan	2,01	100,9	1.15	0.5%	0.067
	Butan	2,70	133,9	1.15	0.5%	0.067
	Biogas (40–75 % Methan) 3)	1,01 - 1,46	15,9 - 29,9	0.48	82%	0.038
Fernwärme	Fernwärme, Durchschnitt 4)			0.85	7.0%	0.044
Elektrizität	CH-Verbrauchermix			2.97	14.9%	0.045

1) Dichte und Brennwert sind von der Holzart und Feuchtigkeit abhängig
2) Werte pro Normal Kubikmeter (0 °C, 101300 Pa)
3) Die Dichte sinkt, und der Brennwert steigt mit dem Methangehalt.
4) Der angegeben Defaultwert basiert auf dem Durchschnitt der Energieträgeranteile der schweizerischen Fernwärmeversorgungen und der Annahme von Verteilverlusten von 20 %.

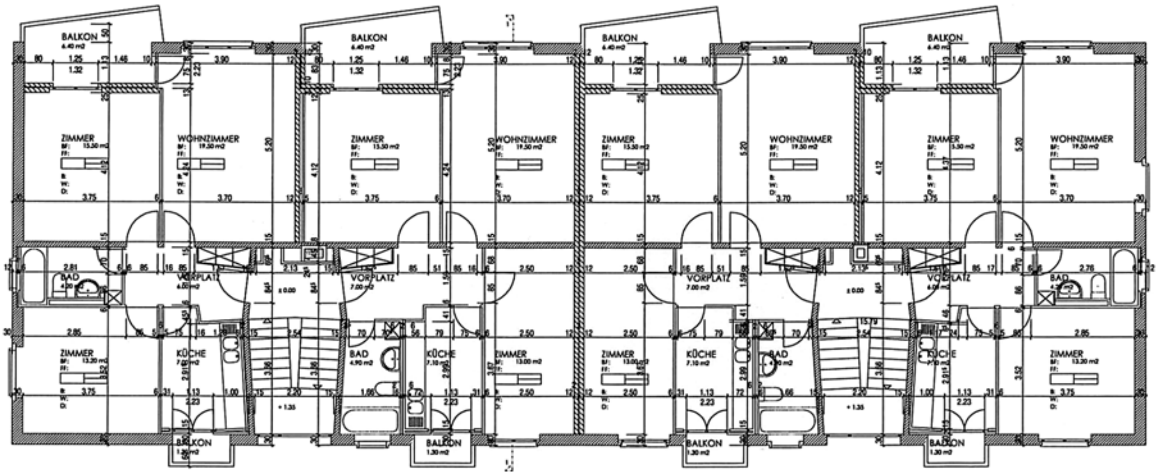
The French translation was also distributed.

May 31, 2008 / rev. June 6, 2008 /G. Zweifel, with additions July 15, 2008

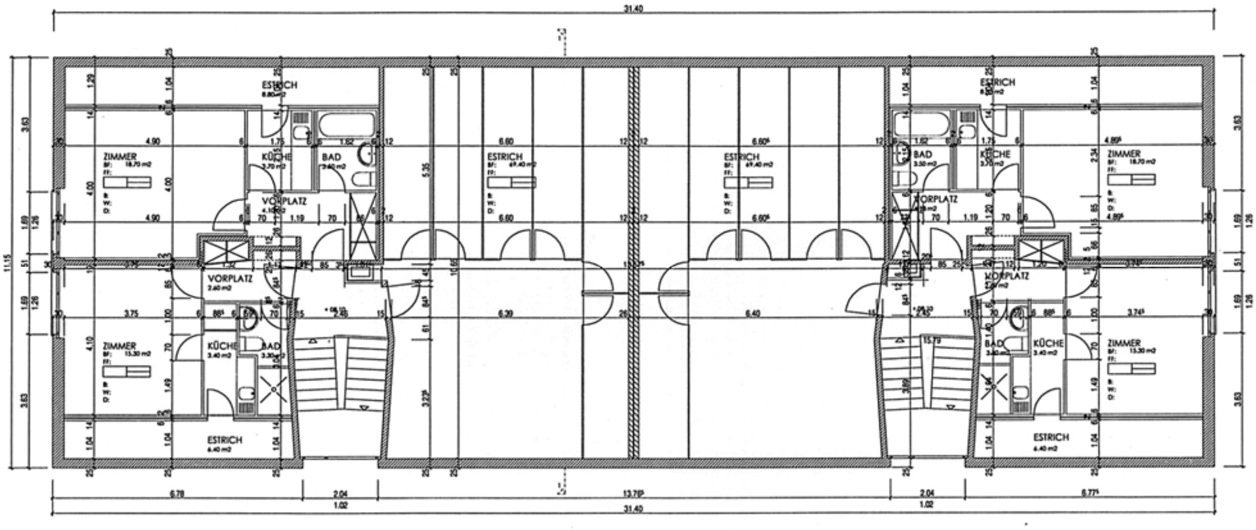
Appendix B
Plans of the Original Building



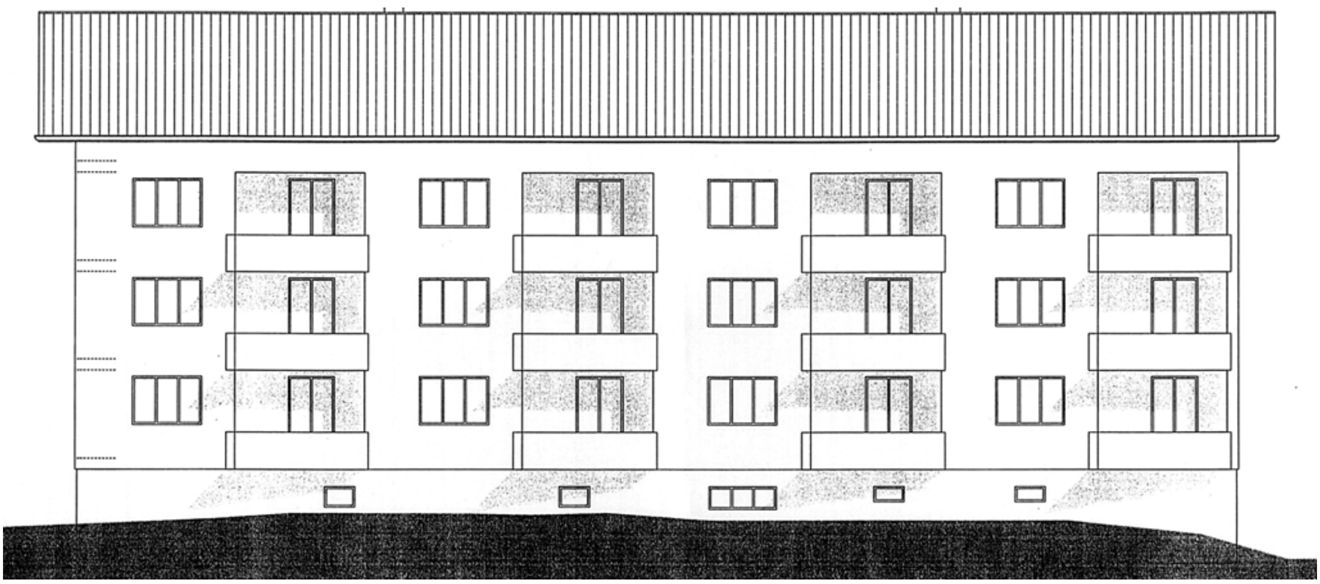
Floor plan basement



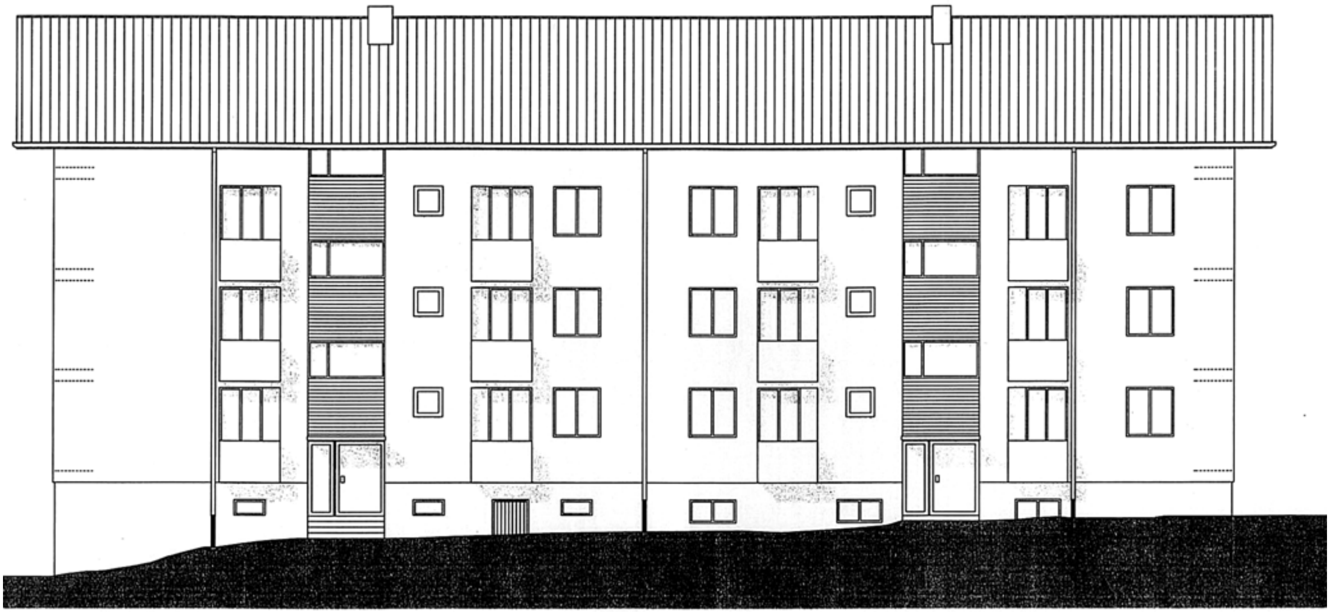
Floor plan regular floor



Floor plan attic



South-west facade view



North-east facade view

South-east and north-west facade views

Appendix C
Step 3 retrofit strategy

Plans from Swiss retrofit team provided by
Robert Fischer, Lucerne University of Applied Sciences and Arts

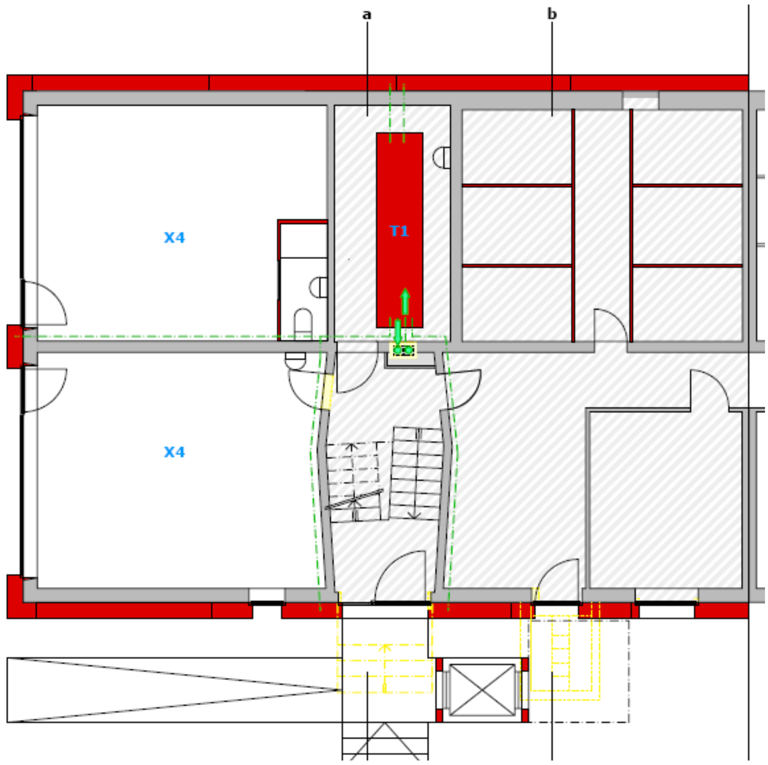


Figure B.1: Basement floor plan

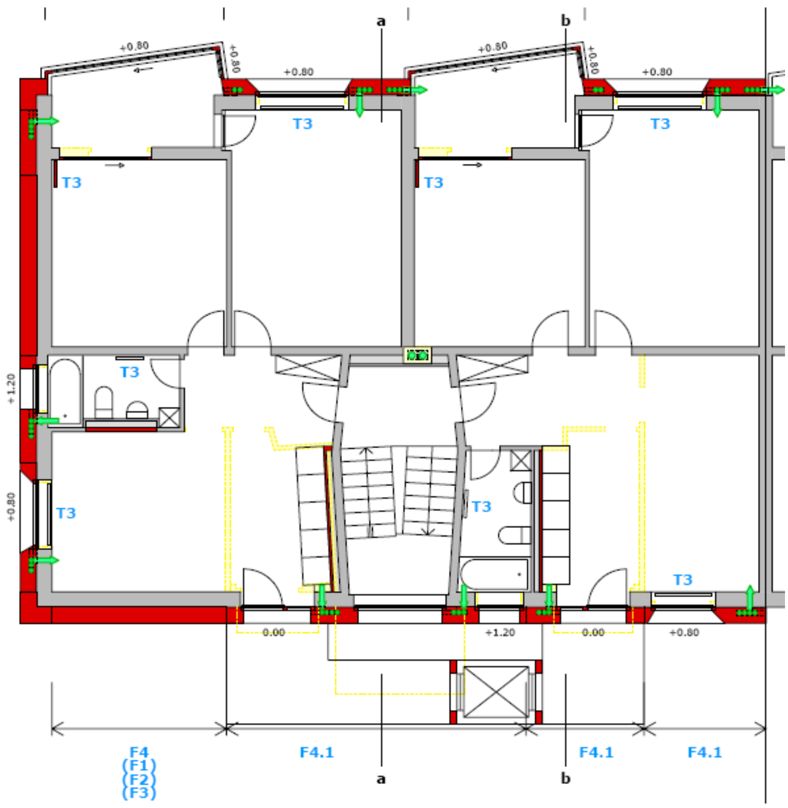


Figure B.2: Regular floor plan

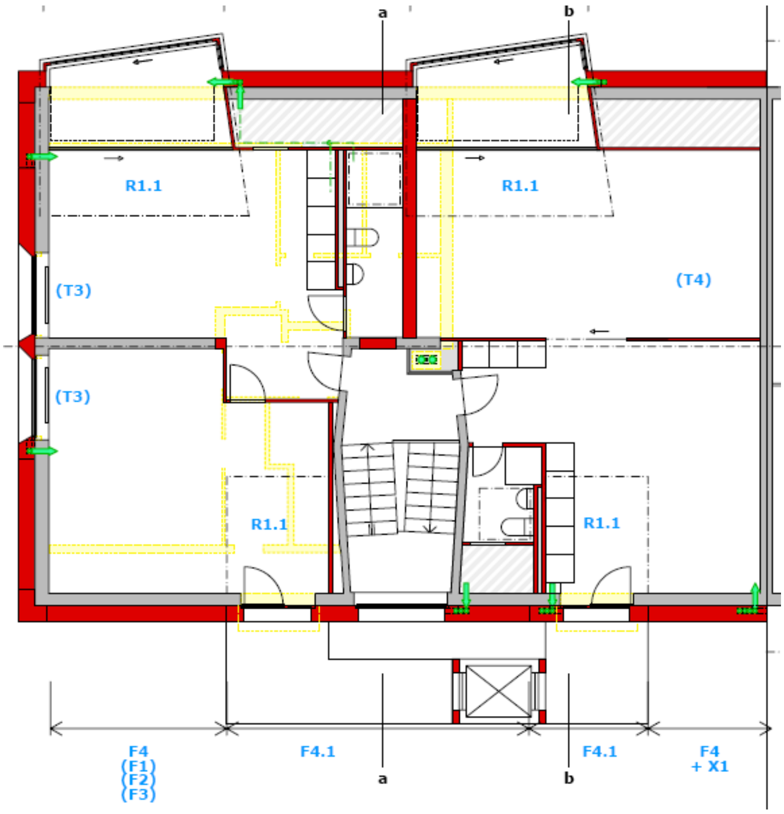


Figure B.3: Attic floor plan

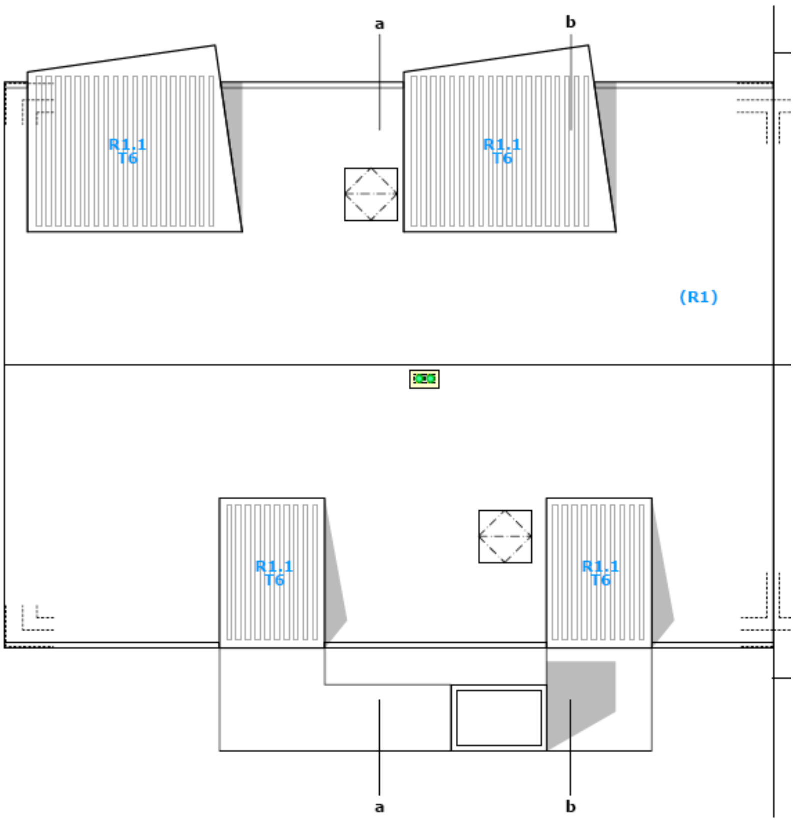


Figure B.4: Rooftop view

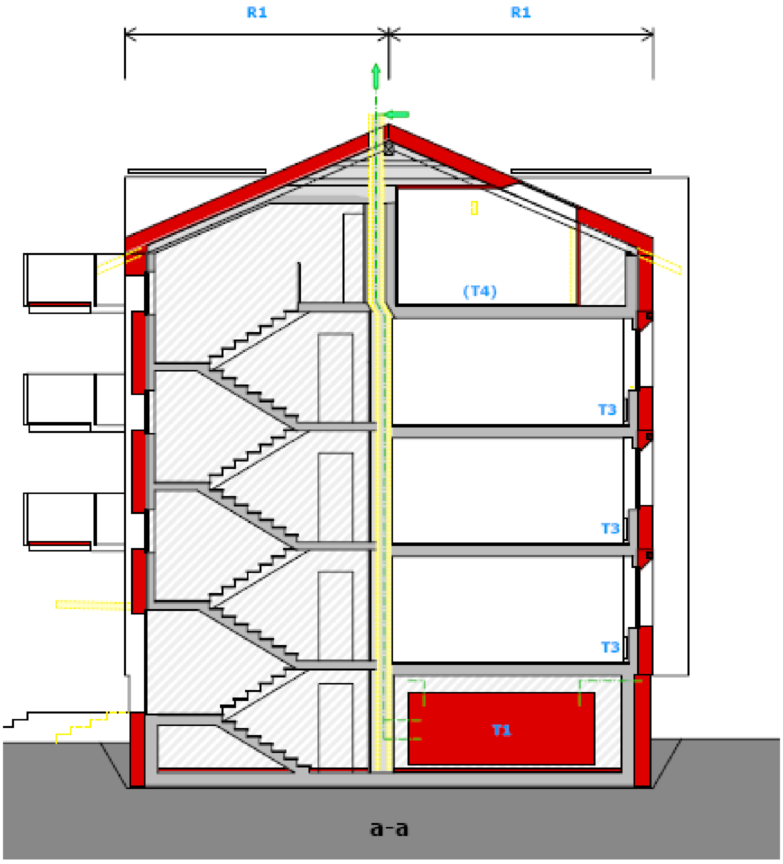


Figure B.5: Cross section a-a

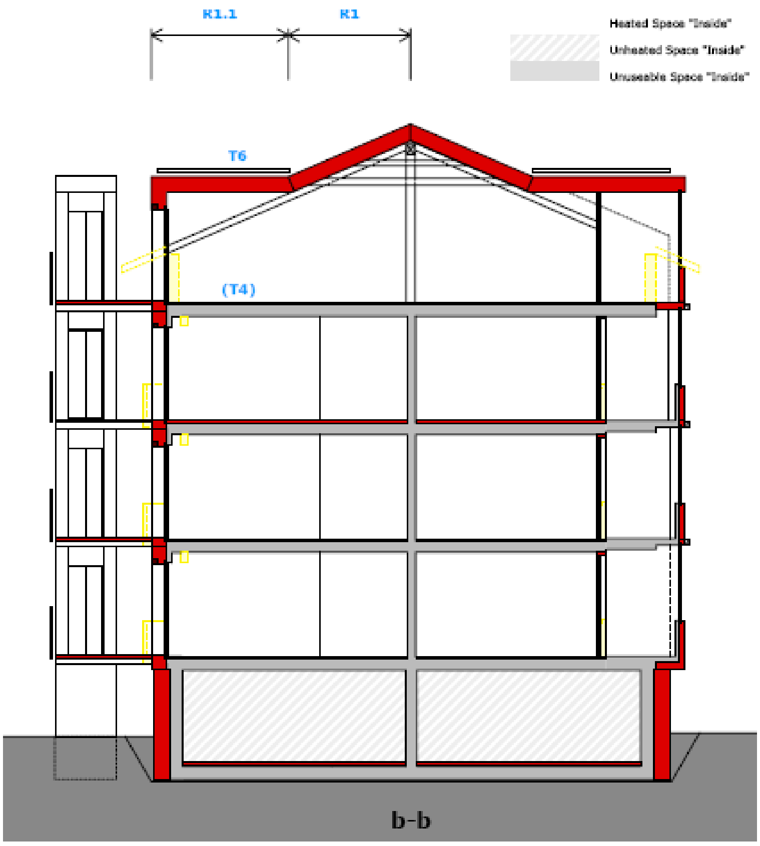


Figure B.5: Cross section b-b

Appendix D
Step 3 Retrofit Case - Specification

1. Building Changes

1.1. Principal changes

The principal changes at the building are

- Addition of an access addition on the NE-side, consisting of a lift tower and access balconies on the floors 2 to 5.
- Inclusion of the former garages in the basement as multi purpose heated spaces, with direct access from outside (or from the stair case, 1 room)
- Inclusion of the former balconies on the south-west façade in the heated space by putting a new facade around. No new balconies on this side
- Addition of modules with flat roof in limited areas on the attic floor

1.2. Geometry

The building geometry can be taken from the plans in Appendix C.

1.2.1. Added floor area

Due to added space areas in the attic and the basement and the inclusion of the balconies, the floor areas are considerably bigger. The gross heated area given does not include the added construction thickness.

Building gross heated area: 782.5 m^2
Net used area (staircase excluded): 635 m^2

Another area depending on the added construction thickness adds to the gross heated area:

Added area = Perimeter length x added thickness.

The perimeter length is 158 m.

1.2.2. NE-Access addition

The lift tower can be seen in the b-b cut and in the floor plans level 2 to 4. On level 2 there is no access balcony for the left hand flat (seen from stair case entry) because there is the ramp.

The balconies have semi transparent balustrades.

1.2.3. Basement

The two new rooms are the size of the former garages. Their opening on the SE-side can be assumed to be of the size of the former garage doors. The rest of the basement (shaded area) is left as unheated space but despite included in the insulation perimeter.

1.2.4. SW-Balconies

The new walls around the former balconies are glazed from the top of the former balustrade to the bottom of the next floor. The balustrades are insulated. This is the case for the whole perimeter of the balconies.

Part of the former exterior wall and the balustrade below the window towards the balconies are removed and replaced by a sliding door.

1.2.5. Attic floor

Four new modules are added to the attic floor. They are indicated by the dot-and-dash lines. On the SW side they follow the shape of the balconies below.

Except for a few small areas (shaded) there are no unheated rooms on the attic floor.

1.2.6. Window sizes

The sizes of the windows are taken from the existing geometry, except for the new access doors on the NE side which are wider than the balcony doors before, including also the small strip aside which had a special construction before.

1.3. Constructions

1.3.1. Exterior walls

Insulation is added to the existing walls where there are no changes. The thickness is one of the parameters to be figured out by the calculation

The new modules in the attic space are prefabricated wood frame construction with appropriate insulation, including the roof. The inside layer is plasterboard.

1.3.2. Roof

The sloped roof is replaced and will have an appropriate insulation layer. The inside finish can be assumed to be plaster board.

1.3.3. Air tightness and infiltration

The building will have an air tightness according to an n_{50} value of 1.0. An according air exchange rate of shall be applied for the untightness of the building shell.

The hygienic ventilation is provided by mechanical ventilation (see below).

2. Building Use

The same building use shall be applied as for the step 2 calculations, adjusted to the new floor area.

3. Domestic hot water

3.1. Consumption

Same value as step 2

3.2. Distribution

Annual efficiency: 0.9

3.3. Generation

The generation of the DHW shall have a solar contribution. The new flat roof parts are foreseen for this, using vacuum tube collectors mounted flat on the roof. Building permission problems are one reason for this, therefore this may not be the solution for your countries case.

The solar contribution shall follow the possibilities of the country’s climate and regulations.

4. Ventilation system

A central mechanical ventilation system is added, with the air handling unit in the basement and supply/return ducts in the insulation layer of the new façade. It has a heat recovery with an annual efficiency of 0.8.

5. Heating system

5.1. Distribution and emission

There are radiators will remain in use, but will be operated on a lower temperature according to the new building shell.

5.2. Generation

In the Swiss case the new generation system will be an oil fired CHP (combined heat and power) unit (1 central unit for more buildings).

6. Cases to be calculated

Building as described, with the same boundary conditions as for step 2. The insulation level and window properties and the solar contribution shall be determined in order to reach the primary energy target of

- 30 kWh/(m^2·y)
- 50 kWh/(m^2·y)

7. Reporting

7.1. Useful heating energy demand

Useful energy demand for heating Q_h shall be reported in relation to the building gross heated area.

7.2. Delivered energy demand

The delivered energy (oil) for heating and DHW shall be reported in relation to the building gross heated area, showing the solar contribution.

7.3. Construction choices

U-values of constructions in order to reach the primary energy target:

	30 kWh / (m^2·y)		**50 kWh / (m^2·y)**	
Construction	**Insulation thickness, cm**	**U-value, W / (m^2·K)**	**Insulation thickness, cm**	**U-value, W / (m^2·K)**
Exterior walls				
Basement interior walls to non-heated zone				
Balcony floor				
Interior roof in contact with attic non-heated zone				
Window frame	--		--	
Glazing	--		--	

g-values of glazing selected in order to reach the primary energy target:

- 30 kWh/(m^2·y): 50 kWh/(m^2·y):

Solar collectors selected in order to reach the primary energy target:

	30 kWh / (m^2·y)		**50 kWh / (m^2·y)**	
Type of collector	**Area, m^2**	**Heat production kWh / (m^2·y)**	**Area, m^2**	**Heat production kWh / (m^2·y)**

July 25, 2008 / rev. Dec 22, 2008 / G. Zweifel

Appendix E
Step 1 and 2 Calculation Reports for Simplified Calculations

1. University of Liège

Synthèse des résultats Outil de calcul PEB - CALE 2

Architecte : **N° de dossier :**
Maître de l'ouvrage : **Date :**

Niveau K	Niveau Ew	Risque de surchauffe		Emission de CO_2 [t/an]	Coût annuel [€/an]	Consommation kWh/m² an
94	193	1	0% : pas de risque	38,42		258
		2	Pas de 2° secteur			

SYNTHESE DES CRITERES :

Niveau d'isolation thermique globale selon la NBN B 62-301 :	K 94	
Niveau de consommation d'énergie primaire (cf. Charte "CALE 2", onglet "An.2_crit", critère 4) :	Ew 193	
Consommation d'énergie primaire annuelle :	525.252	MJ
Consommation d'énergie primaire annuelle de référence :	272.249	MJ
Indicateur de surchauffe (cf. Charte "CALE 2", onglet "An.2_crit", critère 5) :	0% : pas de risque	

SYNTHESE DES RESULTATS EN ENERGIE PRIMAIRE PAR POSTE :

Chauffage		
Consommation :	439.530	MJ
Référence :	181.943	MJ
Part de la consommation totale :	84%	
Eau chaude sanitaire		
Consommation :	73.918	MJ
Référence :	60.361	MJ
Part de la consommation totale :	14%	
Auxiliaires		
Consommation :	11.804	MJ
Référence :	29.945	MJ
Part de la consommation totale :	2%	
Refroidissement		
Consommation :	0	MJ
Référence :	0	MJ
Part de la consommation totale :	0%	
Photovoltaïque		
Economie d'énergie :	0	MJ

SYNTHESE DES RESULTATS EN ENERGIE FINALE PAR TYPE D'ENERGIE :

Combustibles	Consommations (énergie finale)	Coûts annuels * (redevances comprises)
électricité	1.312 kWh	0 €
gaz naturel	0 m^3	0 €
mazout	13.474 litres	0 €
propane	0 litres	0 €
charbon	0 tonnes	0 €
butane	0 kg	0 €
LPG	0 litres	0 €
bois	0,00 stères	0 €
pellets	0,00 tonnes	0 €

* les coûts unitaires sont à introduire à la ligne 276 de l'onglet "Niveau Ew"

Synthèse des résultats

Outil de calcul PEB - CALE 2

Architecte :
Maître de l'ouvrage :

N° de dossier :
Date :

Niveau K	Niveau Ew	Risque de surchauffe		Emission de CO_2 [t/an]	Coût annuel [€/an]	Consommation kWh/m² an
94	**193**	1	0% : pas de risque	38,42		258
		2	Pas de 2° secteur			

SYNTHESE DES RESULTATS PAR SECTEUR

Surface de déperdition totale A_T [m^2] :	960
Surface de fenêtres [m^2] :	78
Surface de plancher chauffée A_{ch} [m^2] :	565
Volume protégé [m^3] :	1.874
Type de construction (classe d'inertie) :	Lourd
Chauffage	
Coefficient de déperdition par transmission H_T [W/K] :	1.186
Coefficient de déperdition par ventilation H_V [W/K] :	151
Besoins nets en énergie [MJ/m²] :	494,46
Rendement du système [%] :	77%
Rendement de production [%] :	83%
Consommation en énergie primaire [MJ] :	439.530
Economie d'énergie primaire grâce au système solaire thermique [MJ] :	0
Part de la consommation due aux pertes par transmission [%] :	89%
Part de la consommation due aux pertes par ventilation [%] :	11%
Eau chaude sanitaire	
Consommation en énergie primaire [MJ] :	73.918
Economie d'énergie primaire grâce au système solaire thermique [MJ] :	0
Auxiliaires	
Consommation en énergie primaire [MJ] :	11.804
Photovoltaïque	
Production en énergie finale [kWh] :	0
Risque de surchauffe	
Degrés-heures de surchauffe par rapport à 18°C [Kh] :	4.417
Probabilité conventionnelle d'installation de refroidissement actif [%] :	0%
Refroidissement	
Consommation "fictive" en énergie primaire [MJ] :	0
Consommation en cas d'installation de refroidissement actif [MJ] :	12.112

Synthèse des résultats Outil de calcul PEB - CALE 2

Architecte : **N° de dossier :**
Maître de l'ouvrage : **Date :**

Niveau K	Niveau Ew	Risque de surchauffe		Emission de CO_2 [t/an]	Coût annuel [€/an]	Consommation kWh/m² an
94	178	1	0% : pas de risque	35,42		238
		2	Pas de 2° secteur			

SYNTHESE DES CRITERES :

Niveau d'isolation thermique globale selon la NBN B 62-301 : **K 94**

Niveau de consommation d'énergie primaire (cf. Charte "CALE 2", onglet "An.2_crit", critère 4) :

Ew 178

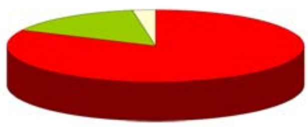
Consommation d'énergie primaire annuelle :	484.259	MJ
Consommation d'énergie primaire annuelle de référence :	272.249	MJ

Indicateur de surchauffe (cf. Charte "CALE 2", onglet "An.2_crit", critère 5) :

0% : pas de risque

SYNTHESE DES RESULTATS EN ENERGIE PRIMAIRE PAR POSTE :

Chauffage		
Consommation :	398.537	MJ
Référence :	181.943	MJ
Part de la consommation totale :	82%	
Eau chaude sanitaire		
Consommation :	73.918	MJ
Référence :	60.361	MJ
Part de la consommation totale :	15%	
Auxiliaires		
Consommation :	11.804	MJ
Référence :	29.945	MJ
Part de la consommation totale :	2%	
Refroidissement		
Consommation :	0	MJ
Référence :	0	MJ
Part de la consommation totale :	0%	
Photovoltaïque		
Economie d'énergie :	0	MJ



SYNTHESE DES RESULTATS EN ENERGIE FINALE PAR TYPE D'ENERGIE :

Combustibles	Consommations (énergie finale)	Coûts annuels * (redevances comprises)
électricité	1.312 kWh	0 €
gaz naturel	0 m^3	0 €
mazout	12.398 litres	0 €
propane	0 litres	0 €
charbon	0 tonnes	0 €
butane	0 kg	0 €
LPG	0 litres	0 €
bois	0,00 stères	0 €
pellets	0,00 tonnes	0 €

* les coûts unitaires sont à introduire à la ligne 276 de l'onglet "Niveau Ew"

Synthèse des résultats Outil de calcul PEB - CALE 2

Architecte : **N° de dossier :**
Maître de l'ouvrage : **Date :**

Niveau K	Niveau Ew	Risque de surchauffe		Emission de CO_2 [t/an]	Coût annuel [€/an]	Consommation kWh/m² an
94	178	1	0% : pas de risque	35,42		238
		2	Pas de 2° secteur			

SYNTHESE DES RESULTATS PAR SECTEUR

Surface de déperdition totale A_T [m^2] :	960
Surface de fenêtres [m^2] :	78
Surface de plancher chauffée A_{ch} [m^2] :	565
Volume protégé [m^3] :	1.874
Type de construction (classe d'inertie) :	Lourd
Chauffage	
Coefficient de déperdition par transmission H_T [W/K] :	1.186
Coefficient de déperdition par ventilation H_V [W/K] :	151
Besoins nets en énergie [MJ/m²] :	448,34
Rendement du système [%] :	77%
Rendement de production [%] :	83%
Consommation en énergie primaire [MJ] :	398.537
Economie d'énergie primaire grâce au système solaire thermique [MJ] :	0
Part de la consommation due aux pertes par transmission [%] :	89%
Part de la consommation due aux pertes par ventilation [%] :	11%
Eau chaude sanitaire	
Consommation en énergie primaire [MJ] :	73.918
Economie d'énergie primaire grâce au système solaire thermique [MJ] :	0
Auxiliaires	
Consommation en énergie primaire [MJ] :	11.804
Photovoltaïque	
Production en énergie finale [kWh] :	0
Risque de surchauffe	
Degrés-heures de surchauffe par rapport à 18°C [Kh] :	3.734
Probabilité conventionnelle d'installation de refroidissement actif [%] :	0%
Refroidissement	
Consommation "fictive" en énergie primaire [MJ] :	0
Consommation en cas d'installation de refroidissement actif [MJ] :	4.911

Additional hypotheses

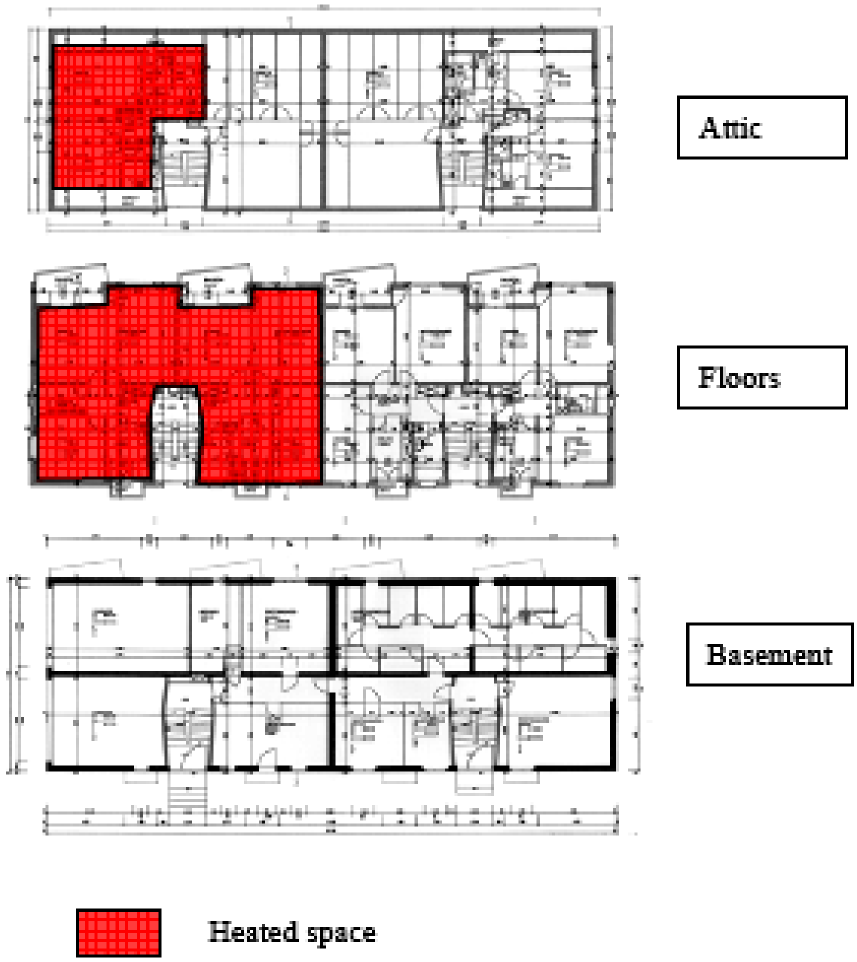
1. Number of persons living in this part of the building : 14
2. Air exchange rate : 0.3 h^{-1} → $(0.3*V)/S_{heated}$ = (0.3*1874)/959.9 = 0.6 m³/(m²·h)
3. U value: cf. attached file
4. Global radiation

Global radiation, sum	horizontal	102	162	305	394	496	529	557	493	334	206	109	80
	NE	55	82	139	171	218	236	246	212	144	91	51	42
	SE	110	156	240	245	271	272	297	296	236	175	102	84
	NW	52	82	134	157	198	214	224	196	140	92	51	39
	SW	107	156	234	231	250	250	275	280	232	177	102	82
MJ/m²	SE/SW	108	156	237	238	260	261	286	288	234	176	102	83
	NE/NW	54	82	137	164	208	225	235	204	142	92	51	40
	30° NE/NO	86	136	250	318	401	428	451	397	271	168	90	67
	30°SE/SW	108	166	292	352	428	451	479	437	311	203	111	85

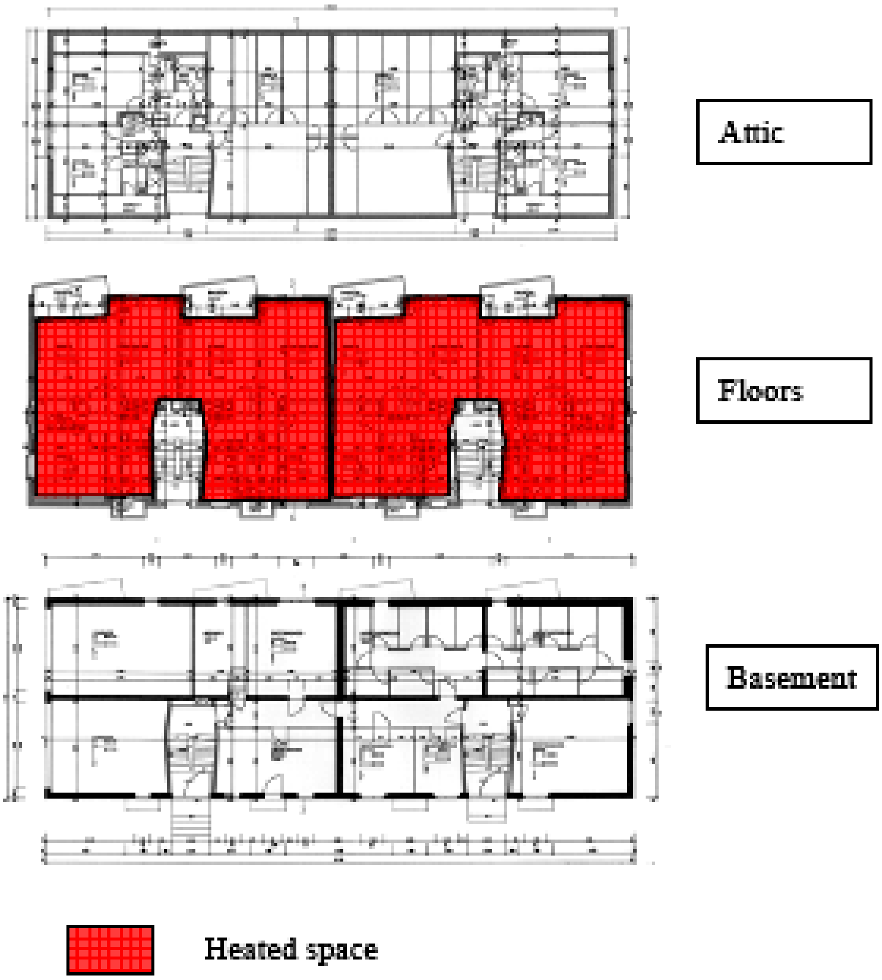
1. All the geometrical calculations : cf. attached file
2. For the Swiss climate, the monthly outdoor temperatures in July and in Augustus were higher than the indoor one. It's never the case in Belgium. So the calculation didn't work, and I had to make few changes which are listed below :
    a. Losses through the envelope and through the ventilation for July and Augustus = 0 MJ
    b. Use of solar gains in July and in Augustus (use for the heating) is equal to zero too.
    c. Risk of overheating is maximum in July and in Augustus (due to solar gain, I therefore consider that all the solar gains could be taken in consideration η=1)

2. University of Brno

2.1. Areas



Gerhard Zweifel	rooms												net area (staircase excluded)	
Attic	18.7	3.7	3.6	4.1	2.6	15.3	3.4	3.3					54.73	
3. floor	15.5	19.5	4.2	6	13.2	7	15.5	19.5	7	4.9	7.1	13	132.4	
2. floor	15.5	19.5	4.2	6	13.2	7	15.5	19.5	7	4.9	7.1	13	132.4	
1.floor	15.5	19.5	4.2	6	13.2	7	15.5	19.5	7	4.9	7.1	13	132.4	
Basement														
												total	452	m^2



Ondřej Šikula	rooms											net area (staircase excluded)
Attic	0	0	0	0	0	0	0	0	0	0	0	0	0
3. floor	15.5	19.5	4.2	6	13.2	7	15.5	19.5	7	4.9	7.1	13	132.4
2. floor	15.5	19.5	4.2	6	13.2	7	15.5	19.5	7	4.9	7.1	13	132.4
1.floor	15.5	19.5	4.2	6	13.2	7	15.5	19.5	7	4.9	7.1	13	132.4
Basement	0	0	0	0	0	0	0	0	0	0	0	0	0
													397 m²

parts 2

2.2. Step 1 results

Month	Sum/Mean		1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating [kWh]	Unheated attic space	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Flats in 3 floor	42'478	8'579.56	7'082.95	4'526.98	3'458.72	0.00	0.00	0.00	0.00	1'108.65	3'436.38	6'107.74	8'177.00
	Flats in 2 floor	22'096	4'847.82	3'756.02	2'113.95	1'511.19	0.00	0.00	0.00	0.00	337.91	1'634.68	3'346.57	4'547.74
	Flats in 1 floor	39'848	8'045.38	6'621.51	4'482.65	3'309.44	0.00	0.00	0.00	0.00	1'015.05	3'161.56	5'615.38	7'596.57
	Unheated basement	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	104'421	21'472.76	17'460.48	11'123.58	8'279.35	0.00	0.00	0.00	0.00	2'461.61	8'232.62	15'069.69	20'321.31
qTransmission [kWh]	Unheated attic space	1'661	267.38	222.98	206.11	201.75	0.00	0.00	0.00	0.00	132.64	166.67	211.48	251.67
	Flats in 3 floor	-52'918	-8'445.56	-7'329.69	-5'511.27	-4'652.17	-1'442.89	-1'697.40	-1'591.31	-1'389.02	-2'286.79	-4'178.00	-6'296.15	-8'097.39
	Flats in 2 floor	-32'877	-4'721.31	-4'020.68	-3'143.87	-2'749.04	-1'477.55	-1'742.69	-1'631.70	-1'437.27	-1'540.38	-2'393.69	-3'544.10	-4'475.13
	Flats in 1 floor	-50'635	-7'913.97	-6'882.77	-5'504.46	-4'555.24	-1'482.85	-1'747.52	-1'636.69	-1'444.23	-2'220.13	-3'918.02	-5'810.07	-7'519.37
	Unheated basement	2'713	492.83	386.11	227.71	265.98	0.00	0.00	0.00	0.00	184.93	270.90	407.61	476.65
	Sum	-136'430	-21'080.84	-18'233.14	-14'159.60	-11'956.45	-4'403.29	-5'187.61	-4'859.70	-4'270.52	-6'047.30	-10'489.71	-15'650.32	-20'091.89
qInfiltration [kWh]	Unheated attic space	-1'661	-267.38	-222.98	-206.11	-201.75	0.00	0.00	0.00	0.00	-132.64	-166.67	-211.48	-251.67
	Flats in 3 floor	-4'457	-808.13	-682.35	-514.69	-445.41	0.00	0.00	0.00	0.00	-235.12	-400.20	-605.47	-765.99
	Flats in 2 floor	-4'460	-802.37	-677.84	-516.66	-450.80	0.00	0.00	0.00	0.00	-248.38	-401.08	-602.10	-760.42
	Flats in 1 floor	-4'464	-807.31	-681.70	-515.92	-447.42	0.00	0.00	0.00	0.00	-239.88	-401.39	-604.92	-765.10
	Unheated basement	-2'713	-492.83	-386.11	-227.71	-265.98	0.00	0.00	0.00	0.00	-184.93	-270.90	-407.61	-476.65
	Sum	-13'381	-2'417.81	-2'041.89	-1'547.27	-1'343.63	0.00	0.00	0.00	0.00	-723.38	-1'202.67	-1'812.49	-2'291.51
qSunRad [kWh]	Unheated attic space	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Flats in 3 floor	12'367	350.00	636.33	1'174.86	1'325.19	1'442.89	1'697.40	1'591.31	1'389.02	1'099.59	817.70	480.21	362.26
	Flats in 2 floor	12'711	351.73	649.74	1'222.45	1'374.98	1'477.55	1'742.69	1'631.70	1'437.27	1'137.18	835.97	485.96	363.67
	Flats in 1 floor	12'721	351.77	650.19	1'213.60	1'379.55	1'482.85	1'747.52	1'636.69	1'444.23	1'131.28	833.72	485.94	363.76
	Unheated basement	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	37'799	1'053.50	1'936.26	3'610.91	4'079.72	4'403.29	5'187.61	4'859.70	4'270.52	3'368.05	2'487.39	1'452.11	1'089.69
qPeople [kWh]	Unheated attic space	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Flats in 3 floor	2'466	315.95	285.38	315.95	305.76	0.00	0.00	0.00	0.00	305.76	315.95	305.76	315.95
	Flats in 2 floor	2'466	315.95	285.38	315.95	305.76	0.00	0.00	0.00	0.00	305.76	315.95	305.76	315.95
	Flats in 1 floor	2'466	315.95	285.38	315.95	305.76	0.00	0.00	0.00	0.00	305.76	315.95	305.76	315.95
	Unheated basement	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	7'399	947.85	856.14	947.85	917.28	0.00	0.00	0.00	0.00	917.28	947.85	917.28	947.85
qEquipment [kWh]	Unheated attic space	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Flats in 3 floor	9	1.18	1.07	1.18	1.14	0.00	0.00	0.00	0.00	1.14	1.18	1.14	1.18
	Flats in 2 floor	9	1.18	1.07	1.18	1.14	0.00	0.00	0.00	0.00	1.14	1.18	1.14	1.18
	Flats in 1 floor	9	1.18	1.07	1.18	1.14	0.00	0.00	0.00	0.00	1.14	1.18	1.14	1.18
	Unheated basement	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	28	3.54	3.21	3.54	3.42	0.00	0.00	0.00	0.00	3.42	3.54	3.42	3.54
qLighting [kWh]	Unheated attic space	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Flats in 3 floor	55	6.99	6.32	6.99	6.77	0.00	0.00	0.00	0.00	6.77	6.99	6.77	6.99
	Flats in 2 floor	55	6.99	6.32	6.99	6.77	0.00	0.00	0.00	0.00	6.77	6.99	6.77	6.99
	Flats in 1 floor	55	6.99	6.32	6.99	6.77	0.00	0.00	0.00	0.00	6.77	6.99	6.77	6.99
	Unheated basement	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	164	20.97	18.96	20.97	20.31	0.00	0.00	0.00	0.00	20.31	20.97	20.31	20.97
tOutdoor (mean) [°C]	Unheated attic space	9.80	0.60	1.70	7.30	8.60	12.80	17.70	19.10	18.90	14.10	10.10	4.90	1.50
	Flats in 3 floor	9.80	0.60	1.70	7.30	8.60	12.80	17.70	19.10	18.90	14.10	10.10	4.90	1.50
	Flats in 2 floor	9.80	0.60	1.70	7.30	8.60	12.80	17.70	19.10	18.90	14.10	10.10	4.90	1.50
	Flats in 1 floor	9.80	0.60	1.70	7.30	8.60	12.80	17.70	19.10	18.90	14.10	10.10	4.90	1.50
	Unheated basement	9.80	0.60	1.70	7.30	8.60	12.80	17.70	19.10	18.90	14.10	10.10	4.90	1.50
	Mean	9.80	0.60	1.70	7.30	8.60	12.80	17.70	19.10	18.90	14.10	10.10	4.90	1.50
tIndoor (mean) [°C]	Unheated attic space	12.50	4.40	5.30	10.20	11.60	14.50	19.80	21.30	20.90	16.10	12.60	8.00	5.20
	Flats in 3 floor	20.60	20.00	20.00	20.00	20.10	16.90	21.90	23.90	23.70	20.30	20.00	20.00	20.00
	Flats in 2 floor	20.90	20.00	20.00	20.10	20.20	17.70	22.50	24.60	24.40	20.60	20.10	20.00	20.00
	Flats in 1 floor	20.50	20.00	20.00	20.10	20.10	16.90	21.80	23.70	23.50	20.40	20.10	20.00	20.00
	Unheated basement	9.80	0.60	1.70	7.30	8.60	12.80	17.70	19.10	18.90	14.10	10.10	4.90	1.50
	Mean	20.67	20.00	20.00	20.07	20.13	17.17	22.07	24.07	23.87	20.43	20.07	20.00	20.00
AirChange (mean) [hod^{-1}]	Unheated attic space	0.30	0.50	0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50
	Flats in 3 floor	0.20	0.30	0.30	0.30	0.30	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30
	Flats in 2 floor	0.20	0.30	0.30	0.30	0.30	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30
	Flats in 1 floor	0.20	0.30	0.30	0.30	0.30	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30
	Unheated basement	0.30	0.50	0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50
	Mean	0.20	0.30	0.30	0.30	0.30	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.30
Rel. Moisture (mean) [%]	Unheated attic space	56.30	61.40	61.20	55.00	53.90	58.50	41.50	37.50	38.70	68.40	69.50	65.20	64.80
	Flats in 3 floor	51.30	38.90	39.90	45.80	47.20	74.70	54.80	48.30	49.10	69.20	59.70	46.60	41.00
	Flats in 2 floor	50.40	39.20	40.20	45.70	47.00	71.00	52.70	46.30	47.00	67.90	59.70	46.90	41.30
	Flats in 1 floor	51.40	38.90	39.90	45.70	47.10	74.90	55.00	48.80	49.80	68.90	59.60	46.70	41.00
	Unheated basement	53.70	52.60	54.30	55.10	51.50	61.10	45.80	40.30	40.80	66.50	64.90	56.20	55.20
	Mean	51.03	39.00	40.00	45.73	47.10	73.53	54.17	47.80	48.63	68.67	59.67	46.73	41.10

2.3. Step 2 Results

Month	Sum/Mean		1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (31 days)
qHeating [kWh]	Unheated attic space	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Flats in 3 floor	51'070	9'649.75	8'392.30	7'138.42	3'876.59	0.00	0.00	0.00	0.00	1'653.88	3'948.63	6'960.76	9'449.52
	Flats in 2 floor	31'374	6'110.17	5'270.27	4'235.13	1'970.36	0.00	0.00	0.00	0.00	872.66	2'372.81	4'436.74	6'106.26
	Flats in 1 floor	55'415	10'439.33	9'088.64	7'676.14	4'088.06	0.00	0.00	0.00	0.00	1'879.45	4'306.68	7'615.11	10'321.38
	Unheated basement	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	137'859	26'199.25	22'751.21	19'049.69	9'935.01	0.00	0.00	0.00	0.00	4'405.99	10'628.12	19'012.61	25'877.16
qTransmission [kWh]	Unheated attic space	1'765	278.55	262.45	239.77	170.15	0.00	0.00	0.00	0.00	133.15	173.23	221.55	286.51
	Flats in 3 floor	-56'407	-8'758.81	-7'777.54	-7'048.59	-4'673.85	-1'561.30	-1'629.56	-1'821.76	-1'529.65	-2'510.73	-4'188.39	-6'432.99	-8'473.48
	Flats in 2 floor	-36'734	-5'228.57	-4'663.87	-4'156.18	-2'762.33	-1'555.94	-1'627.15	-1'817.69	-1'525.31	-1'728.37	-2'613.93	-3'915.21	-5'139.03
	Flats in 1 floor	-60'528	-9'545.85	-8'468.51	-7'572.53	-4'859.63	-1'521.75	-1'595.62	-1'779.21	-1'492.67	-2'723.13	-4'541.53	-7'084.52	-9'342.83
	Unheated basement	3'426	585.06	537.70	448.72	228.25	0.00	0.00	0.00	0.00	215.29	320.12	474.26	616.24
	Sum	-153'668	-23'533.23	-20'909.92	-18'777.30	-12'295.81	-4'638.99	-4'852.33	-5'418.66	-4'547.63	-6'962.23	-11'343.85	-17'432.72	-22'955.34
qInfiltration [kWh]	Unheated attic space	-1'765	-278.55	-262.45	-239.77	-170.15	0.00	0.00	0.00	0.00	-133.15	-173.23	-221.55	-286.51
	Flats in 3 floor	-8'682	-1'529.92	-1'364.85	-1'205.61	-744.07	0.00	0.00	0.00	0.00	-438.80	-746.18	-1'145.26	-1'507.44
	Flats in 2 floor	-8'652	-1'520.51	-1'356.56	-1'198.28	-748.83	0.00	0.00	0.00	0.00	-445.35	-745.00	-1'138.73	-1'498.55
	Flats in 1 floor	-8'684	-1'532.01	-1'366.70	-1'207.04	-742.61	0.00	0.00	0.00	0.00	-433.30	-746.05	-1'146.99	-1'509.74
	Unheated basement	-3'426	-585.06	-537.70	-448.72	-228.25	0.00	0.00	0.00	0.00	-215.29	-320.12	-474.26	-616.24
	Sum	-26'018	-4'582.44	-4'088.11	-3'610.93	-2'235.51	0.00	0.00	0.00	0.00	-1'317.45	-2'237.23	-3'430.98	-4'515.73
qSunRad [kWh]	Unheated attic space	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Flats in 3 floor	11'489	314.84	457.32	791.65	1'227.67	1'561.30	1'629.57	1'821.76	1'529.65	981.98	661.81	303.81	207.27
	Flats in 2 floor	11'481	314.78	457.40	795.20	1'227.13	1'555.94	1'627.15	1'817.69	1'525.31	987.39	662.00	303.53	207.20
	Flats in 1 floor	11'267	314.40	453.81	779.30	1'200.51	1'521.75	1'595.63	1'779.21	1'492.66	963.30	656.78	302.74	207.06
	Unheated basement	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	34'236	944.02	1'368.53	2'366.15	3'655.31	4'638.99	4'852.35	5'418.66	4'547.62	2'932.67	1'980.59	910.08	621.53
qPeople [kWh]	Unheated attic space	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Flats in 3 floor	2'466	315.95	285.38	315.95	305.76	0.00	0.00	0.00	0.00	305.76	315.95	305.76	315.95
	Flats in 2 floor	2'466	315.95	285.38	315.95	305.76	0.00	0.00	0.00	0.00	305.76	315.95	305.76	315.95
	Flats in 1 floor	2'466	315.95	285.38	315.95	305.76	0.00	0.00	0.00	0.00	305.76	315.95	305.76	315.95
	Unheated basement	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	7'399	947.85	856.14	947.85	917.28	0.00	0.00	0.00	0.00	917.28	947.85	917.28	947.85
qEquipment [kWh]	Unheated attic space	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Flats in 3 floor	9	1.18	1.07	1.18	1.14	0.00	0.00	0.00	0.00	1.14	1.18	1.14	1.18
	Flats in 2 floor	9	1.18	1.07	1.18	1.14	0.00	0.00	0.00	0.00	1.14	1.18	1.14	1.18
	Flats in 1 floor	9	1.18	1.07	1.18	1.14	0.00	0.00	0.00	0.00	1.14	1.18	1.14	1.18
	Unheated basement	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	28	3.54	3.21	3.54	3.42	0.00	0.00	0.00	0.00	3.42	3.54	3.42	3.54
qLighting [kWh]	Unheated attic space	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Flats in 3 floor	55	6.99	6.32	6.99	6.77	0.00	0.00	0.00	0.00	6.77	6.99	6.77	6.99
	Flats in 2 floor	55	6.99	6.32	6.99	6.77	0.00	0.00	0.00	0.00	6.77	6.99	6.77	6.99
	Flats in 1 floor	55	6.99	6.32	6.99	6.77	0.00	0.00	0.00	0.00	6.77	6.99	6.77	6.99
	Unheated basement	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sum	164	20.97	18.96	20.97	20.31	0.00	0.00	0.00	0.00	20.31	20.97	20.31	20.97
tOutdoor (mean) [°C]	Unheated attic space	8.30	-1.50	-1.20	2.90	8.90	13.10	16.30	18.70	17.80	13.40	9.30	3.40	-1.10
	Flats in 3 floor	8.30	-1.50	-1.20	2.90	8.90	13.10	16.30	18.70	17.80	13.40	9.30	3.40	-1.10
	Flats in 2 floor	8.30	-1.50	-1.20	2.90	8.90	13.10	16.30	18.70	17.80	13.40	9.30	3.40	-1.10
	Flats in 1 floor	8.30	-1.50	-1.20	2.90	8.90	13.10	16.30	18.70	17.80	13.40	9.30	3.40	-1.10
	Unheated basement	8.30	-1.50	-1.20	2.90	8.90	13.10	16.30	18.70	17.80	13.40	9.30	3.40	-1.10
	Mean	8.30	-1.50	-1.20	2.90	8.90	13.10	16.30	18.70	17.80	13.40	9.30	3.40	-1.10
tIndoor (mean) [°C]	Unheated attic space	11.20	2.40	2.80	6.20	11.30	15.40	18.10	21.30	19.90	15.40	11.80	6.60	2.90
	Flats in 3 floor	20.50	20.00	20.00	20.00	20.10	17.90	20.30	24.00	22.90	20.20	20.00	20.00	20.00
	Flats in 2 floor	20.70	20.00	20.00	20.00	20.20	18.80	20.90	24.90	23.80	20.30	20.10	20.00	20.00
	Flats in 1 floor	20.50	20.00	20.00	20.00	20.10	18.00	20.20	24.20	22.90	20.10	20.00	20.00	20.00
	Unheated basement	12.60	5.90	6.20	8.50	11.80	14.90	17.60	20.70	19.90	16.20	13.30	9.50	6.60
	Mean	20.57	20.00	20.00	20.00	20.13	18.23	20.47	24.37	23.20	20.20	20.03	20.00	20.00
AirChange (mean) $[hod^{-1}]$	Unheated attic space	0.30	0.50	0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50
	Flats in 3 floor	0.30	0.40	0.40	0.40	0.40	0.00	0.00	0.00	0.00	0.40	0.40	0.40	0.40
	Flats in 2 floor	0.30	0.40	0.40	0.40	0.40	0.00	0.00	0.00	0.00	0.40	0.40	0.40	0.40
	Flats in 1 floor	0.30	0.40	0.40	0.40	0.40	0.00	0.00	0.00	0.00	0.40	0.40	0.40	0.40
	Unheated basement	0.30	0.50	0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50
	Mean	0.30	0.40	0.40	0.40	0.40	0.00	0.00	0.00	0.00	0.40	0.40	0.40	0.40
Rel. Moisture (mean) [%]	Unheated attic space	58.00	59.30	60.70	56.20	55.90	63.40	53.10	43.50	47.80	65.80	62.00	66.60	62.40
	Flats in 3 floor	45.50	28.80	30.40	32.90	42.40	72.20	61.90	49.30	53.40	59.10	47.60	37.90	30.30
	Flats in 2 floor	44.60	29.00	30.70	33.10	42.20	68.20	59.70	46.80	50.40	58.70	47.60	38.10	30.50
	Flats in 1 floor	45.40	28.70	30.40	32.90	42.40	71.30	62.40	48.90	53.10	59.30	47.60	37.80	30.20
	Unheated basement	53.40	47.30	49.60	48.30	54.20	67.10	56.30	46.50	49.00	62.60	56.50	55.00	48.70
	Mean	45.17	28.83	30.50	32.97	42.33	70.57	61.33	48.33	52.30	59.03	47.60	37.93	30.33

3. University of Minho Results

3.1. Introduction

The Cases 1 and 2 were simulated applying the Portuguese Thermal Regulation (RCCTE) methodology, which is a steady-state calculation method based on the degree-days. Following this methodology we have calculated the useful and delivered energy needs.

As required, all the necessary inputs were the ones given to us in the Specifications Document and the climatic data necessary in case 1 was calculated using the files: Lucerne_monthly.xls; lucerne_ hourly.xls:

Degree-Days= 3362 K·d;

E_{south} (incident south solar energy) = 1.930 kW/(m^2·d);

Heating Period = 7.6 months;

Thermal Amplitude = 9.03 K

Case 2 corresponds to Guimarães, a Potuguese city located in the north of Portugal, 50 km away from the sea:

Degree-Days= 1770 K·d;

E_{south} (incident south solar energy) = 3.1 kW/m^2·d);

Heating Period = 7 months;

Thermal Amplitude = 14 K

3.2. Calculation procedures

Following the RCCTE calculation procedures, the energy needs of each apartment were calculated. The identification of each apartment is the following:

Legend:

B1P1_D -> **B1** – Building 1; **P1** – Floor 1; **D** – right apartment

B1P1_E -> **B1** – Building 1; **P1** – Floor 1; **E** – left apartment

B1P2_D -> **B1** – Building 1; **P2** – Floor 2; **D** – right apartment

B1P2_E -> **B1** – Building 1; **P2** – Floor 2; **E** – left apartment

B1P3_D -> **B1** – Building 1; **P3** – Floor 3; **D** – right apartment

B1P3_E -> **B1** – Building 1; **P3** – Floor 3; **E** – left apartment

B1S_E -> **B1** – Building 1; **S** – attic; **E** – left apartment

B1S_F -> **B1** – Building 1; **S** – attic; **F** – front apartment

B2P1_D -> **B2** – Building 1; **P1** – Floor 1; **D** – right apartment

B2P1_E -> **B2** – Building 1; **P1** – Floor 1; **E** – left apartment

B2P2_D -> **B2** – Building 1; **P2** – Floor 2; **D** – right apartment

B2P2_E -> **B2** – Building 1; **P2** – Floor 2; **E** – left apartment

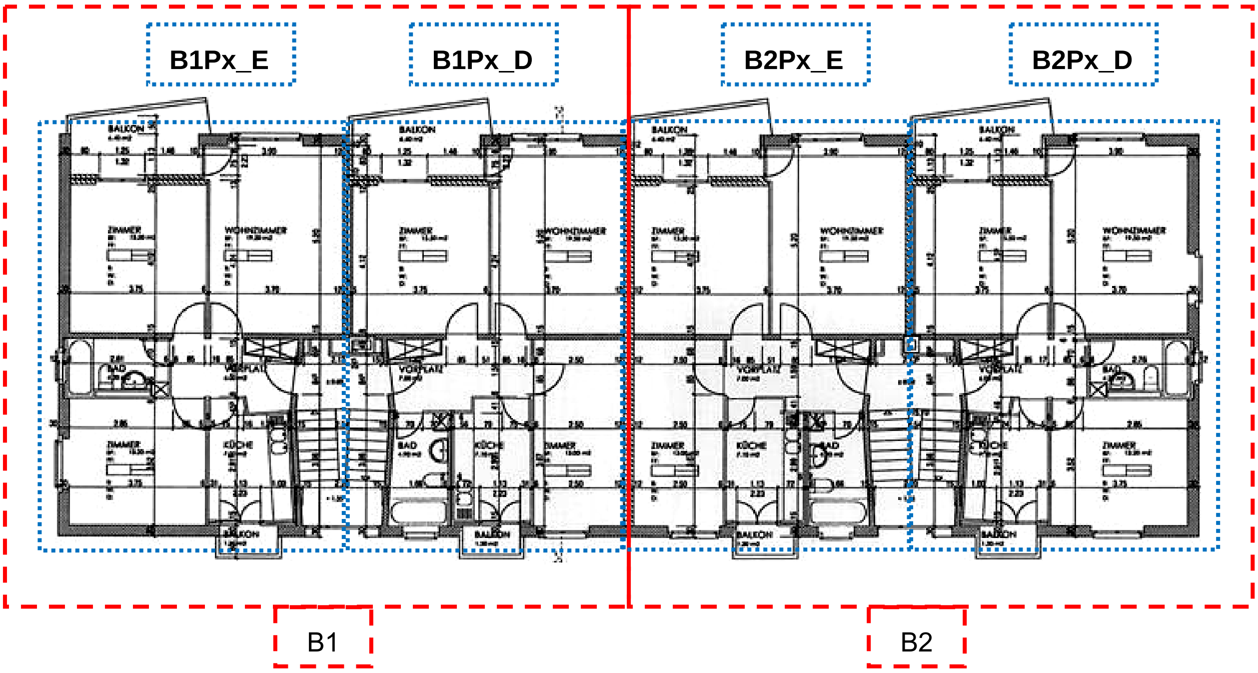
B2P3_D -> **B2** – Building 1; **P3** – Floor 3; **D** – right apartment

B2P3_E -> **B2** – Building 1; **P3** – Floor 3; **E** – left apartment

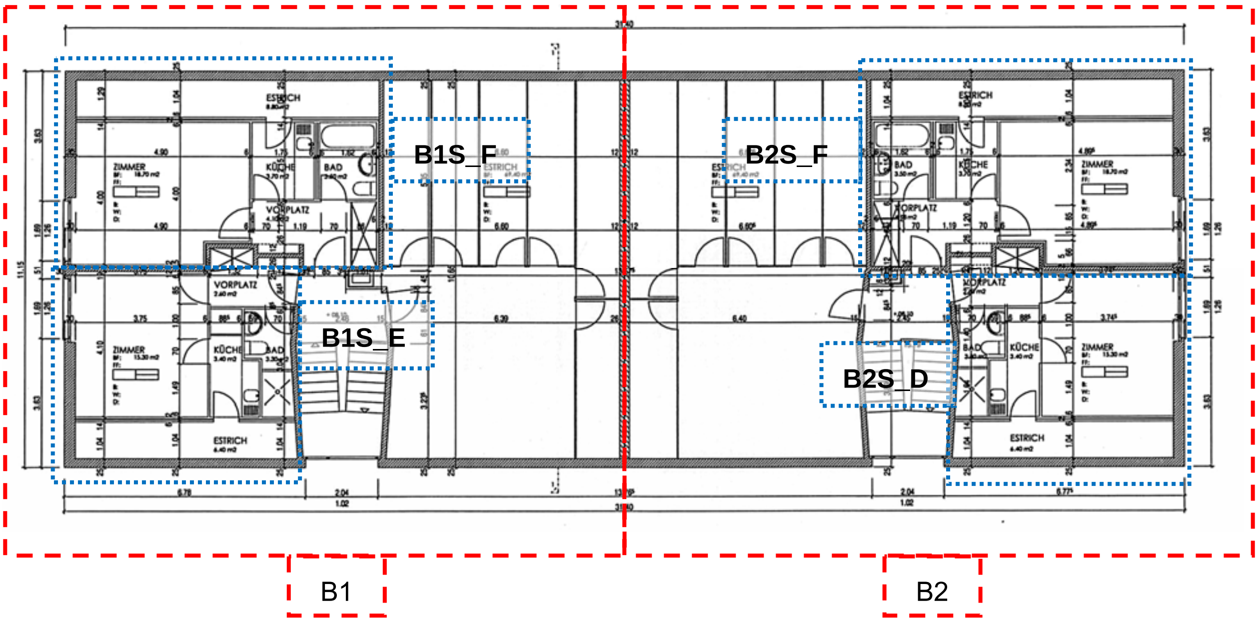
B2S_E -> **B2** – Building 1; **S** – attic; **E** – left apartment

B2S_F -> **B2** – Building 1; **S** – attic; **F** – front apartment

Elfenau floor plans regular



Elfenau floor plans attic



3.3. Results

First, we present the results obtined with the RCCTE tool, which contains the specific and maximum energy needs for heating, cooling and hot water and also the total primary energy comsumption, however the primary energy presented here was calculated applying the Portugues convertion factors.

Apartment	Nic kWh/ (m²·y)	Ni kWh/ (m²·y)	Nvc kWh/ (m²·y)	Nv kWh/ (m²·y)	Nac kWh/ (m²·y)	Na kWh/ (m²·y)	Ntc kWh/ (m²·y)	Nt kWh/ (m²·y)
	Specific heating needs	Maximum heating needs	Specific cooling needs	Maximum cooling needs	Specific hot water needs	Maximum hot water needs	Specific total primary energy needs	Max. total primary energy needs
Case study 1								
B1P1_D	207.13	144.45	0.38	16.00	52.27	46.33	6.72	7.28
B1P1_E	222.21	150.10	0.17	16.00	53.55	47.47	6.99	7.48
B1P2_D	107.45	137.31	0.38	16.00	52.27	46.33	5.65	7.22
B1P2_E	145.54	137.31	0.17	16.00	53.55	47.47	6.17	7.36
B1P3_D	222.72	148.03	0.01	16.00	52.27	46.33	6.89	7.31
B1P3_E	143.95	137.31	0.17	16.00	53.55	47.47	6.15	7.36
B1S_F	249.25	187.49	0.19	16.00	77.83	68.99	9.37	10.52
B1S_E	242.56	179.20	0.02	16.00	94.91	84.13	10.77	12.36
B2P1_D	259.10	163.12	0.14	16.00	53.47	47.39	7.38	7.58
B2P1_E	207.81	144.45	0.38	16.00	52.27	46.33	6.73	7.28
B2P2_D	164.65	137.31	0.14	16.00	53.47	47.39	6.37	7.35
B2P2_E	107.54	137.31	0.38	16.00	52.27	46.33	5.65	7.22
B2P3_D	133.86	137.31	0.23	16.00	53.47	47.39	6.04	7.35
B2P3_E	222.88	148.05	0.48	16.00	52.27	46.33	6.89	7.31
B2S_F	272.61	192.79	0.18	16.00	77.96	69.10	9.64	10.59
B2S_D	251.54	180.86	0.02	16.00	94.91	84.13	10.87	12.37
Case study 2								
B1P1_D	88.79	78.17	3.77	18.00	52.27	46.33	5.46	6.70
B1P1_E	93.78	81.15	3.36	18.00	53.55	47.47	5.62	6.87
B1P2_D	36.38	74.42	4.22	18.00	52.27	46.33	4.90	6.67
B1P2_E	53.12	74.42	3.68	18.00	53.55	47.47	5.19	6.81
B1P3_D	94.53	80.06	0.29	18.00	52.27	46.33	5.51	6.72
B1P3_E	51.19	74.42	3.79	18.00	53.55	47.47	5.17	6.81
B1S_F	113.13	100.83	4.52	18.00	77.83	68.99	7.92	9.76
B1S_E	108.15	96.47	2.28	18.00	94.91	84.13	9.33	11.63
B2P1_D	113.03	88.00	3.11	18.00	53.47	47.39	5.82	6.93
B2P1_E	89.14	78.17	4.21	18.00	52.27	46.33	5.47	6.70
B2P2_D	58.07	74.42	3.11	18.00	53.47	47.39	5.23	6.80
B2P2_E	36.43	74.42	4.21	18.00	52.27	46.33	4.90	6.67
B2P3_D	45.41	74.42	3.89	18.00	53.47	47.39	5.10	6.80
B2P3_E	94.62	80.07	0.29	18.00	52.27	46.33	5.51	6.72
B2S_F	128.04	103.62	4.14	18.00	77.96	69.10	8.09	9.80
B2S_D	115.10	97.34	1.89	18.00	94.91	84.13	9.41	11.64

Legend: Fulfill the regulation (green) | Do not fulfill the regulation (orange)

From these results it was calculated the necessary useful and delivered energy demand for the building, applying the Switzerland conversion factors:

Case study 1 (Lucerne)

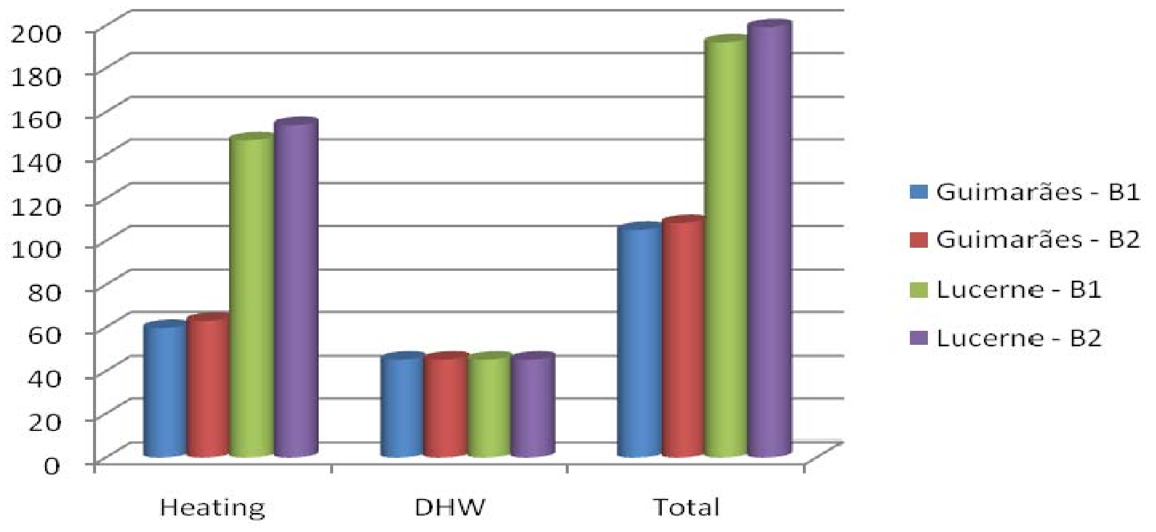
		Heating	DHW	Total
Useful Energy Demand (kWh/(m²·y)	**B1**	146.7	45.5	192.2
	B2	153.9	45.5	199.3
Delivered Energy Demand (kWh/(m²·y)	**B1**	227.4	80.5	308.0
	B2	238.5	80.5	319.0

Case study 2 (Guimarães)

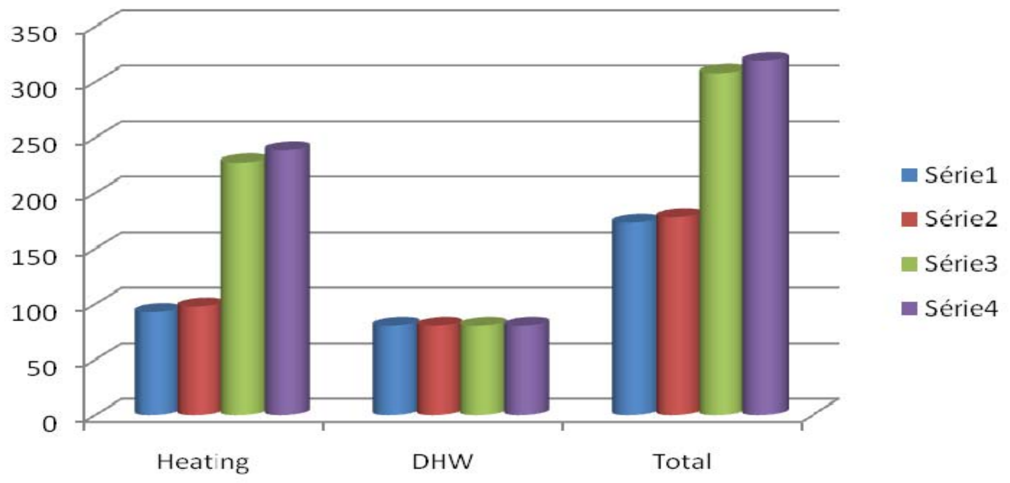
		Heating	DHW	Total
Useful Energy Demand (kWh/(m²·y)	**B1**	59.7	45.5	105.2
	B2	63.0	45.5	108.5
Delivered Energy Demand (kWh/(m²·y)	**B1**	92.5	80.5	173.1
	B2	97.7	80.5	178.2

Below, the results are also presented in a graphical form, for a better comparative analysis:

Useful energy demand (kWh/m²·y)



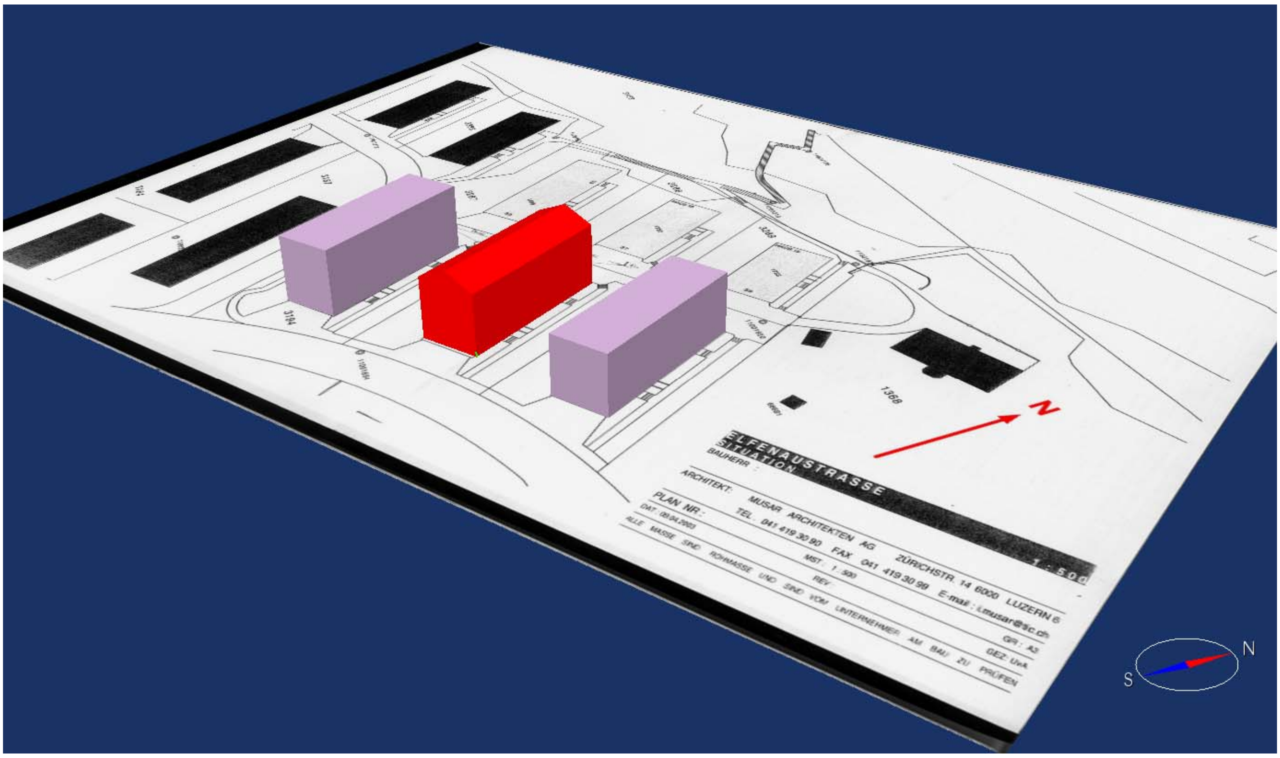
Delivered energy demand (kWh/m²·y)

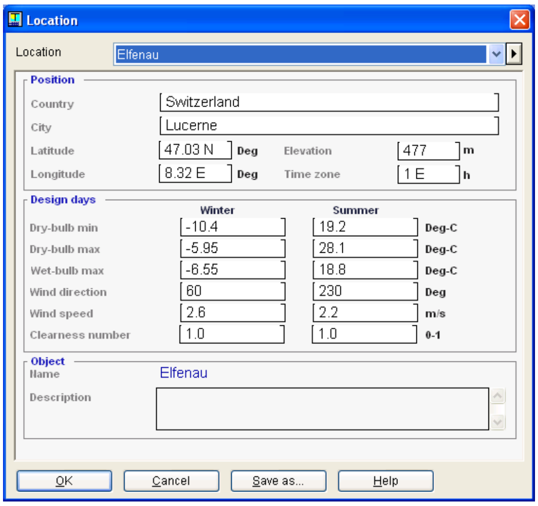


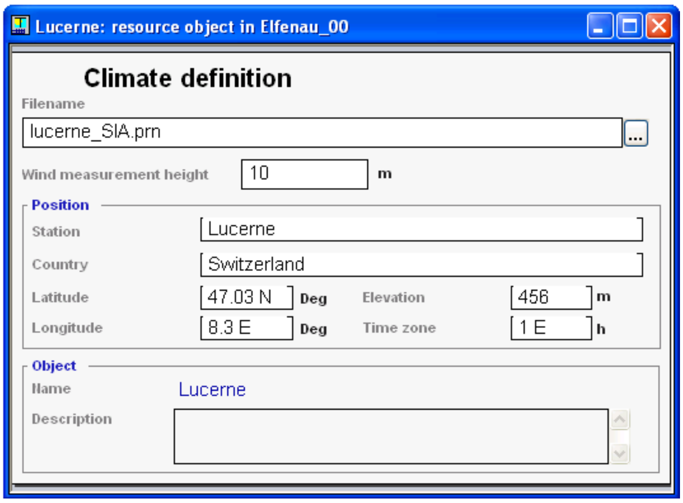
Appendix F
Step 1 and 2 Calculation Report from HSLU

Sven Moosberger, Lucerne University of Applied Sciences and Arts

1. Location, situation and building part to be considered







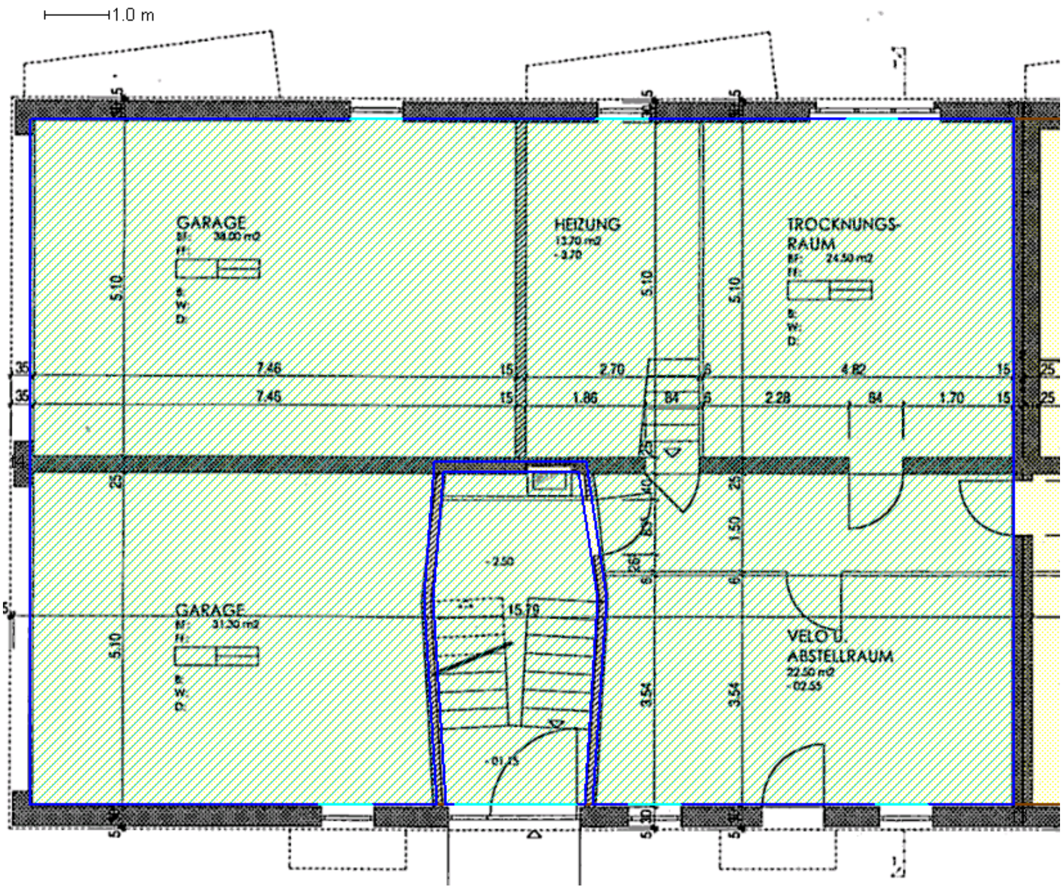
2. Building

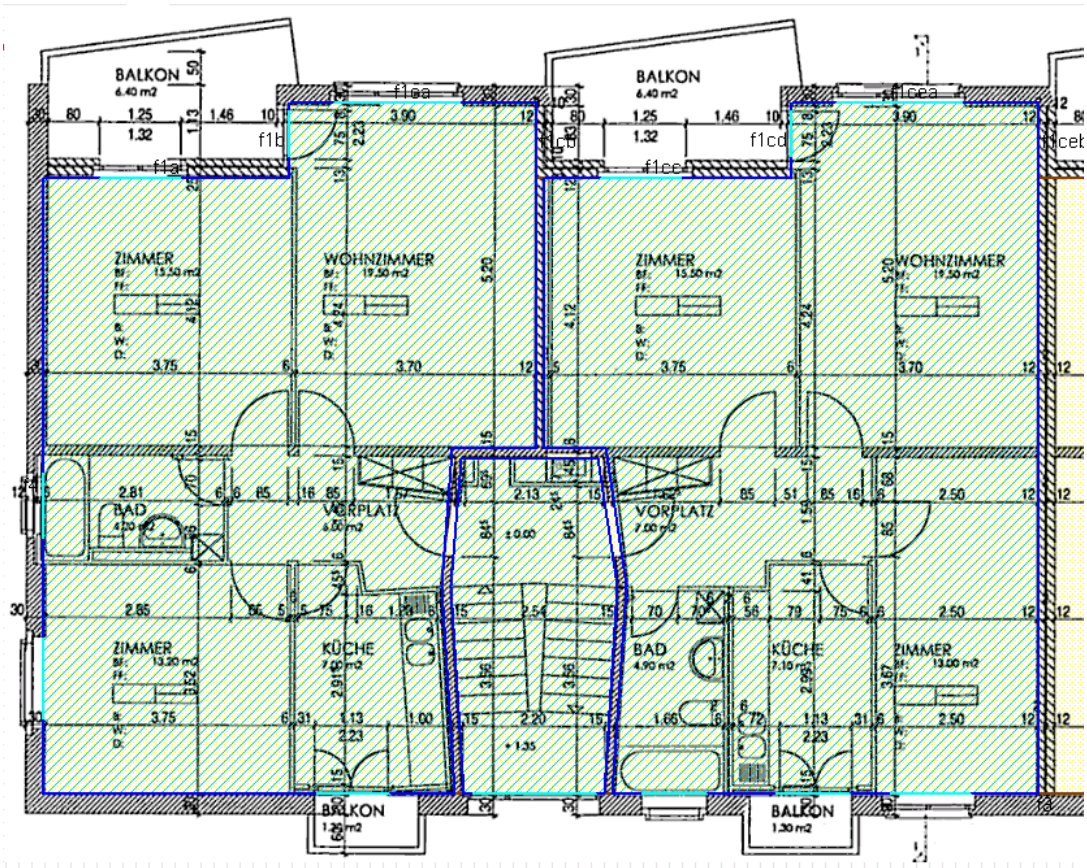
2.1. General

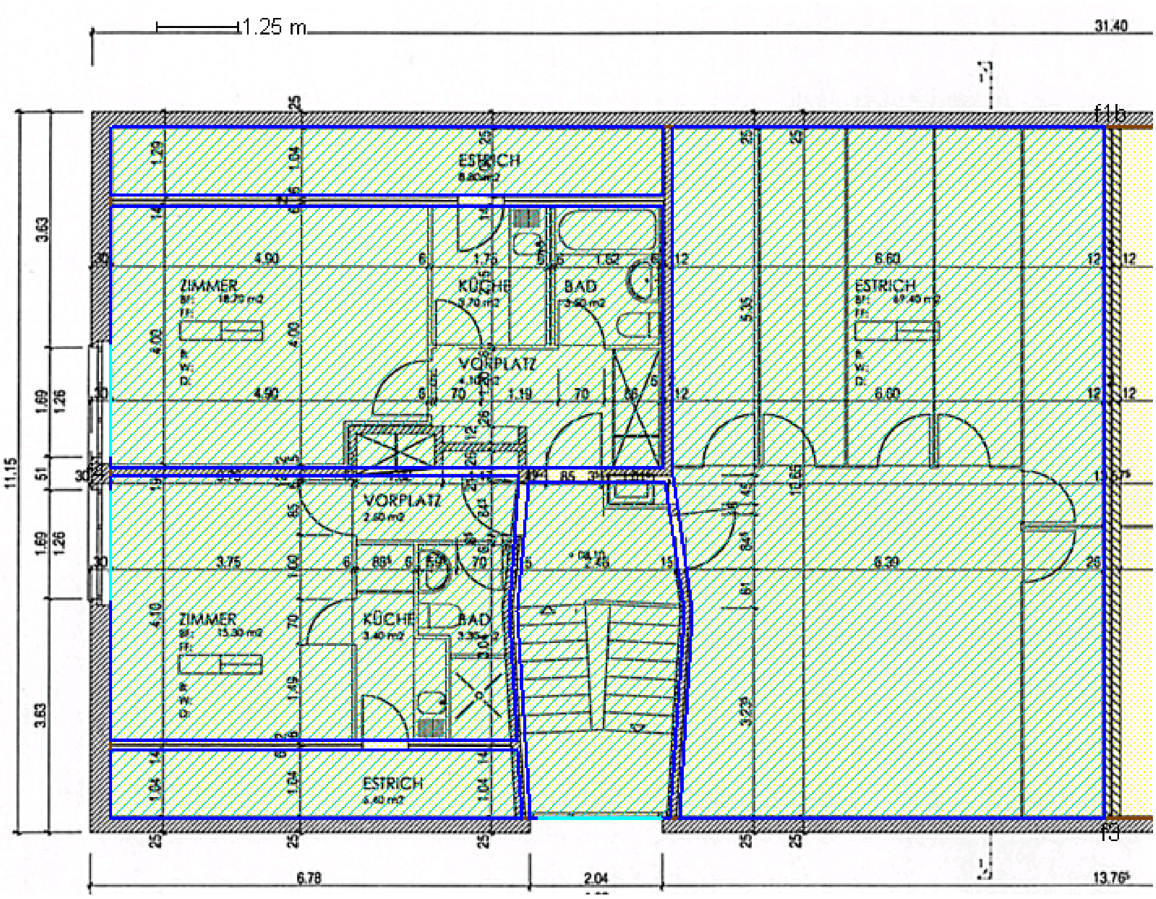
The simulation is done with one zone per flat. Thus the sum of the zone floor areas is smaller than building gross heated area, but bigger than net used area:

Name	Group	Area, m²
Stairhouse	stairhouse	5 x 12
Groundfloor_SE	SE	69
Groundfloor_NW	NW	70.5
Basement	unheated	149
1stfloor_SE	SE	69
1stfloor_NW	NW	70.5
2ndfloor_SE	SE	69
2ndfloor_NW	NW	70.5
AtticStoreNE	unheated	6.5
AtticStoreSW	unheated	9
AtticStoreNW	unheated	70
AtticSW	Attic	34
AtticNE	Attic	25
Building gross	incl. stairh.	539
Net used area	excl. stairh.	478

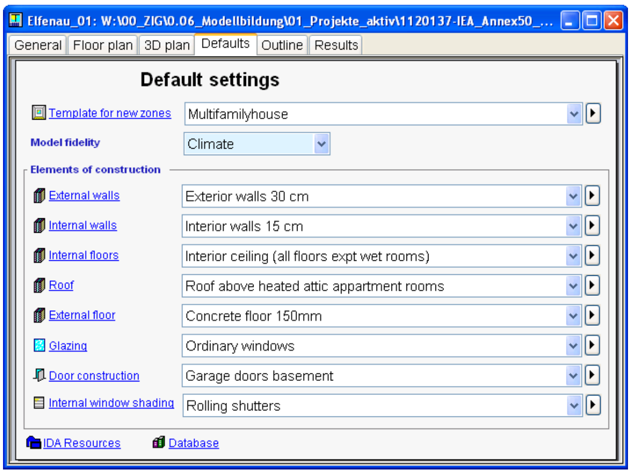
2.2. Geometry

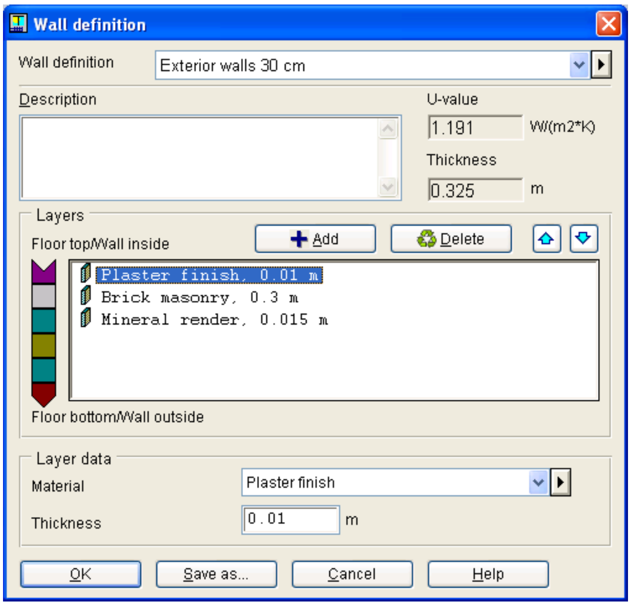


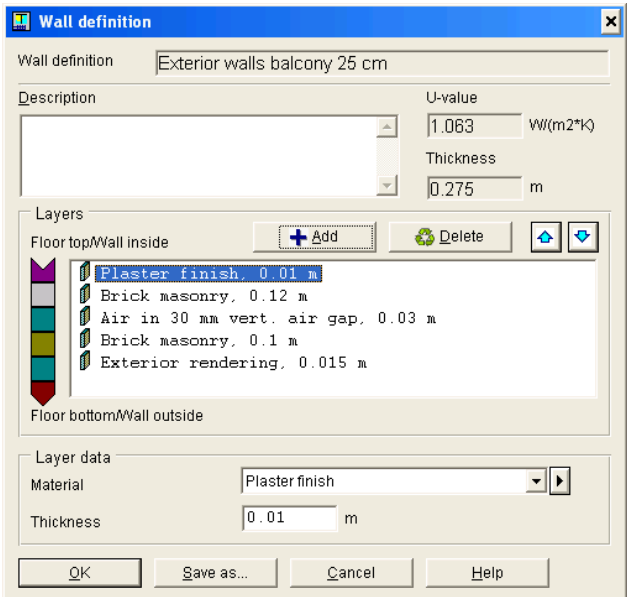

BALKON
f1ea
f1b
f1a
f1cd
f1cea
f1ce
f1ceb
ZIMMER
WOHNZIMMER
ZIMMER
WOHNZIMMER
BAD
VORPLATZ
VORPLATZ
ZIMMER
KÜCHE
BAD
KÜCHE
ZIMMER
BALKON
BALKON

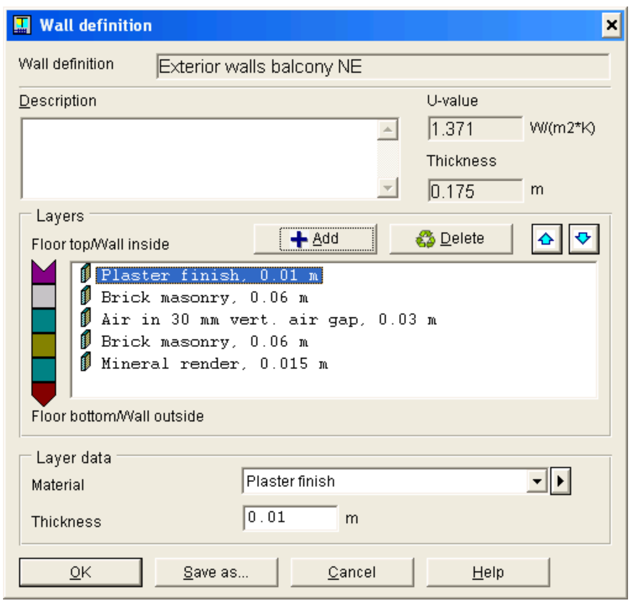

1.25 m
31.40
f1b
ESTRICH
ZIMMER
KÜCHE
BAD
VORPLATZ
ESTRICH
VORPLATZ
ZIMMER
KÜCHE
BAD
ESTRICH
f3
6.78
2.04
13.76

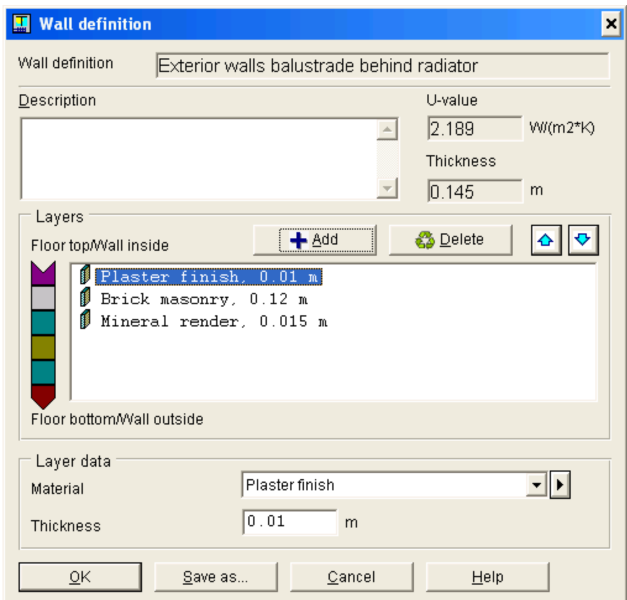
2.3. Constructions

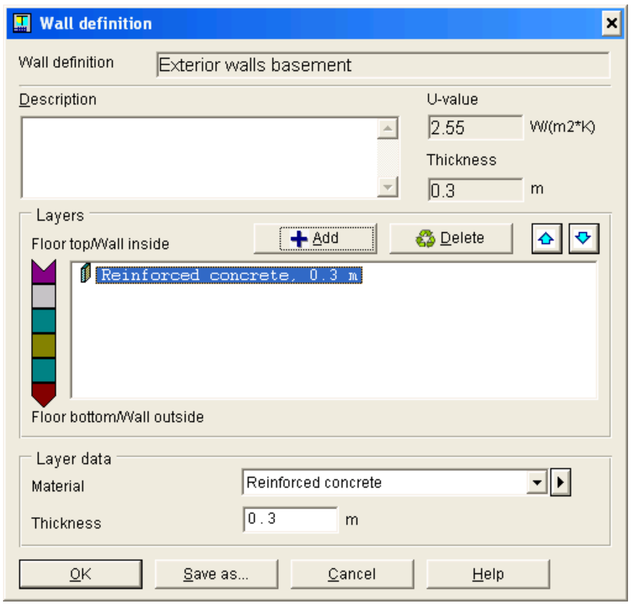


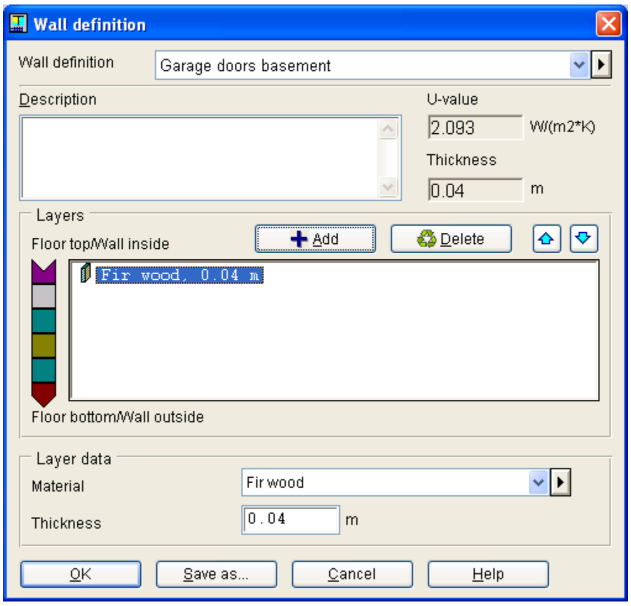


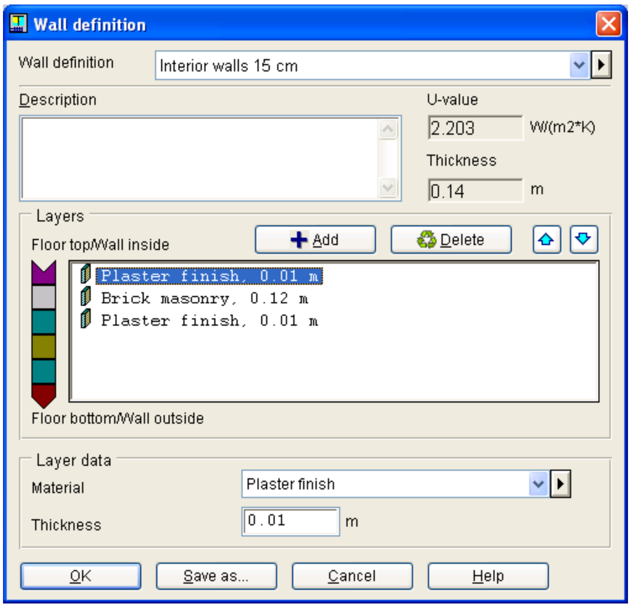


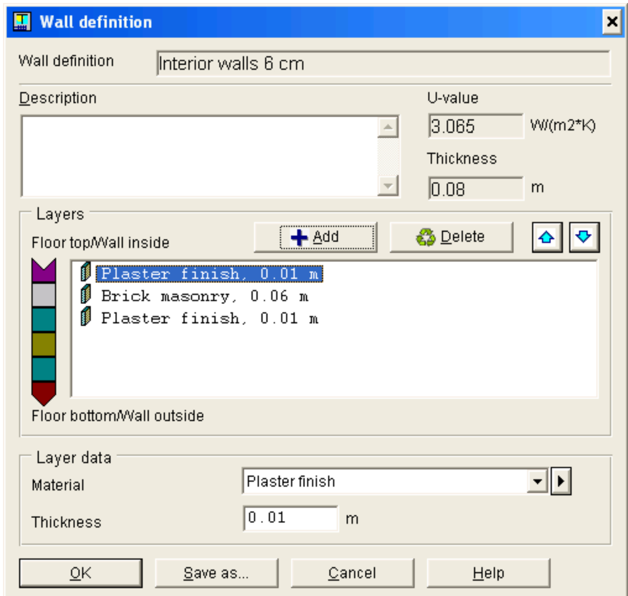


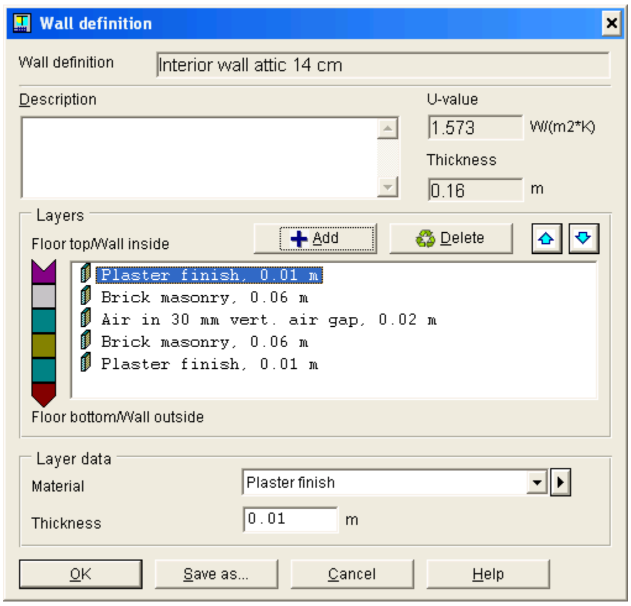


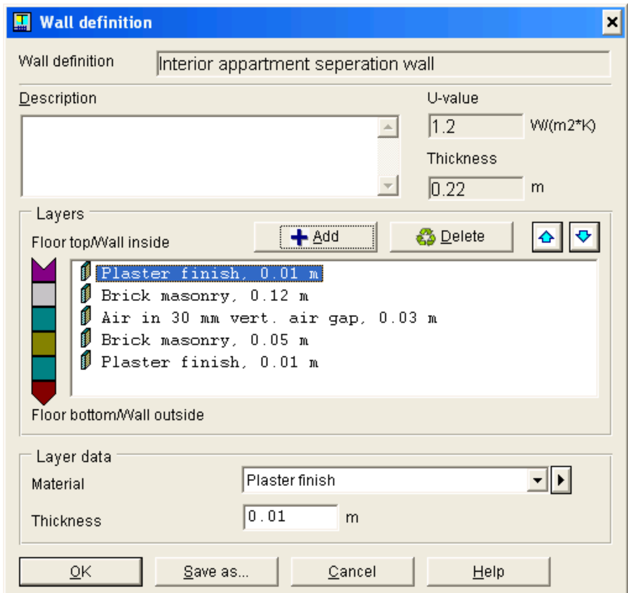

Wall definition
Wall definition Exterior walls basement
Description
U-value 2.55 W/(m2*K)
Thickness 0.3 m
Layers
Floor top/Wall inside
Add Delete
Reinforced concrete, 0.3 m
Floor bottom/Wall outside
Layer data
Material Reinforced concrete
Thickness 0.3 m
OK Save as... Cancel Help

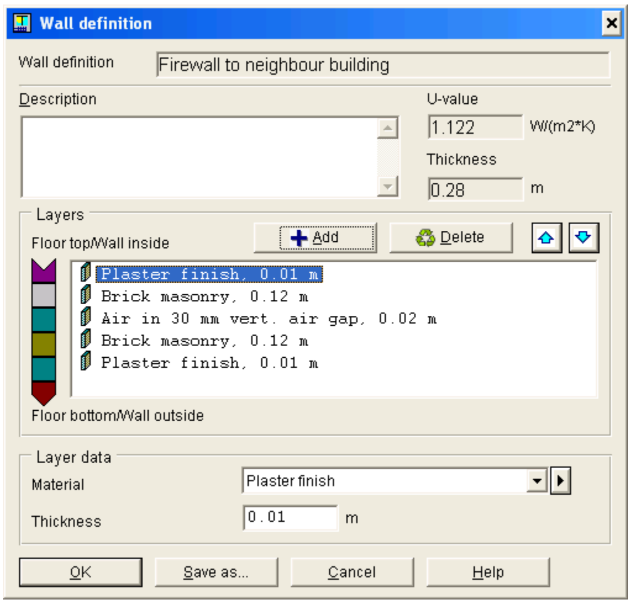

Wall definition
Wall definition Garage doors basement
Description
U-value 2.093 W/(m2*K)
Thickness 0.04 m
Layers
Floor top/Wall inside
Add Delete
Fir wood, 0.04 m
Floor bottom/Wall outside
Layer data
Material Fir wood
Thickness 0.04 m
OK Save as... Cancel Help

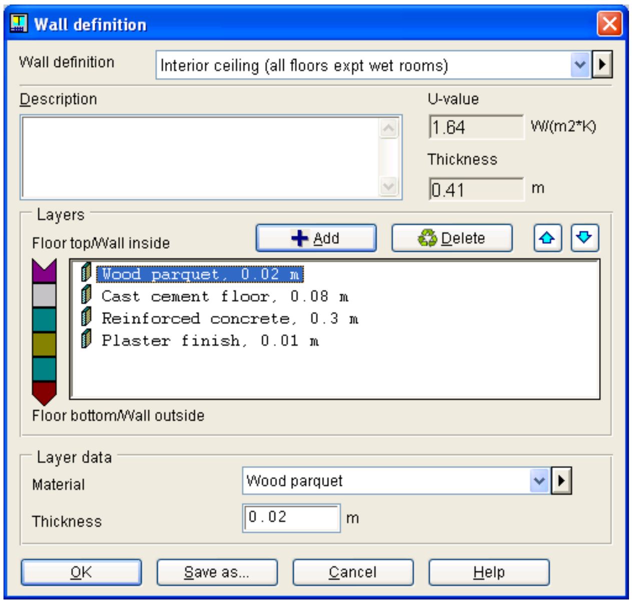

Wall definition
Wall definition Interior walls 15 cm
Description
U-value 2.203 W/(m2*K)
Thickness 0.14 m
Layers
Floor top/Wall inside
Add Delete
Plaster finish, 0.01 m
Brick masonry, 0.12 m
Plaster finish, 0.01 m
Floor bottom/Wall outside
Layer data
Material Plaster finish
Thickness 0.01 m
OK Save as... Cancel Help

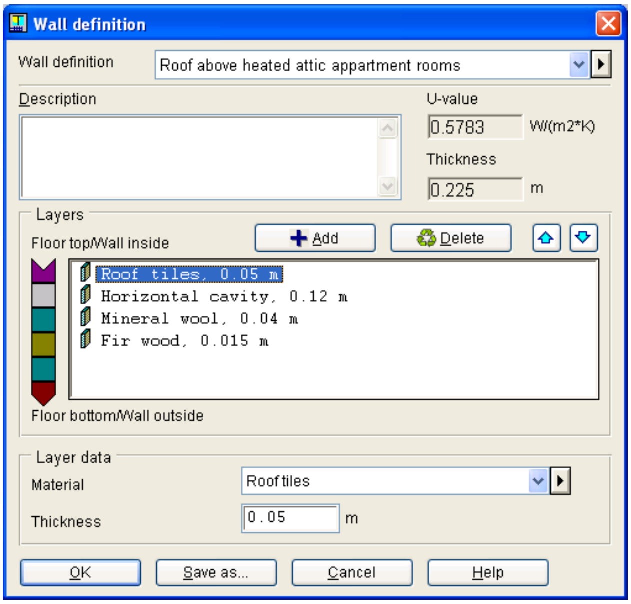

Wall definition
Wall definition Interior walls 6 cm
Description
U-value 3.065 W/(m2*K)
Thickness 0.08 m
Layers
Floor top/Wall inside
Add Delete
Plaster finish, 0.01 m
Brick masonry, 0.06 m
Plaster finish, 0.01 m
Floor bottom/Wall outside
Layer data
Material Plaster finish
Thickness 0.01 m
OK Save as... Cancel Help


Wall definition
Wall definition Interior wall attic 14 cm
Description
U-value 1.573 W/(m2*K)
Thickness 0.16 m
Layers
Floor top/Wall inside
Add Delete
Plaster finish, 0.01 m
Brick masonry, 0.06 m
Air in 30 mm vert. air gap, 0.02 m
Brick masonry, 0.06 m
Plaster finish, 0.01 m
Floor bottom/Wall outside
Layer data
Material Plaster finish
Thickness 0.01 m
OK Save as... Cancel Help


Wall definition
Wall definition Interior appartment seperation wall
Description
U-value 1.2 W/(m2*K)
Thickness 0.22 m
Layers
Floor top/Wall inside
Add Delete
Plaster finish, 0.01 m
Brick masonry, 0.12 m
Air in 30 mm vert. air gap, 0.03 m
Brick masonry, 0.05 m
Plaster finish, 0.01 m
Floor bottom/Wall outside
Layer data
Material Plaster finish
Thickness 0.01 m
OK Save as... Cancel Help


Wall definition
Wall definition
Firewall to neighbour building
Description
U-value
1.122
W/(m2*K)
Thickness
0.28
m
Layers
Floor top/Wall inside
Add
Delete
Plaster finish, 0.01 m
Brick masonry, 0.12 m
Air in 30 mm vert. air gap, 0.02 m
Brick masonry, 0.12 m
Plaster finish, 0.01 m
Floor bottom/Wall outside
Layer data
Material
Plaster finish
Thickness
0.01
m
OK
Save as...
Cancel
Help


Wall definition
Wall definition
Interior ceiling (all floors expt wet rooms)
Description
U-value
1.64
W/(m2*K)
Thickness
0.41
m
Layers
Floor top/Wall inside
Add
Delete
Wood parquet, 0.02 m
Cast cement floor, 0.08 m
Reinforced concrete, 0.3 m
Plaster finish, 0.01 m
Floor bottom/Wall outside
Layer data
Material
Wood parquet
Thickness
0.02
m
OK
Save as...
Cancel
Help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Wall definition
Roof above heated attic appartment rooms
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U-value
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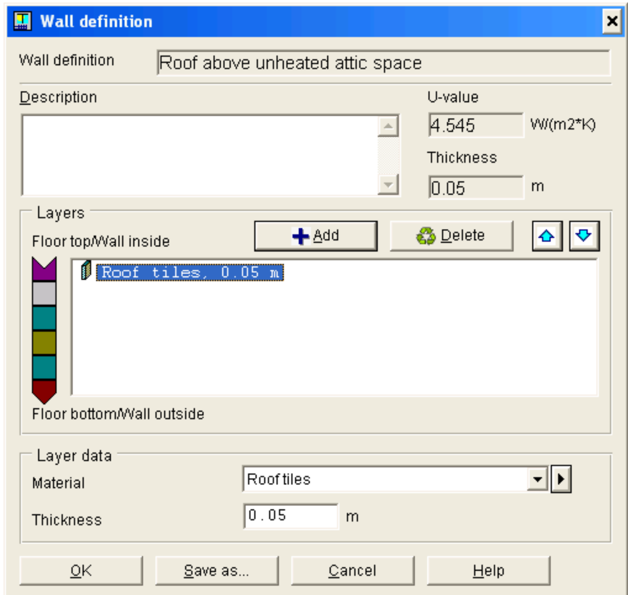
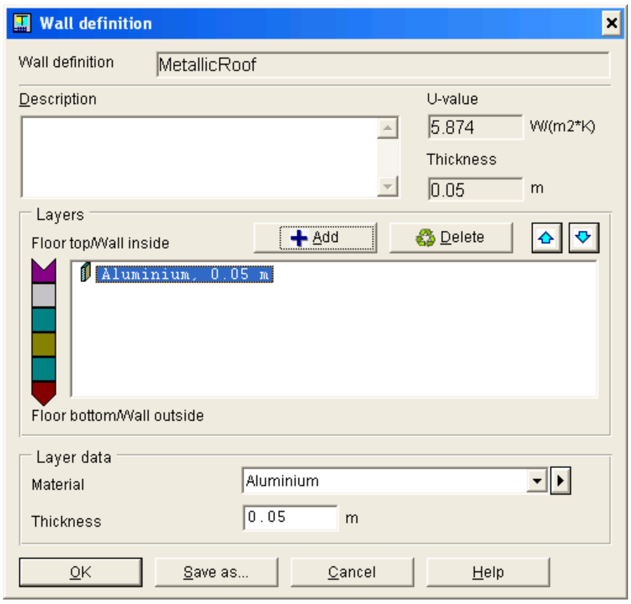
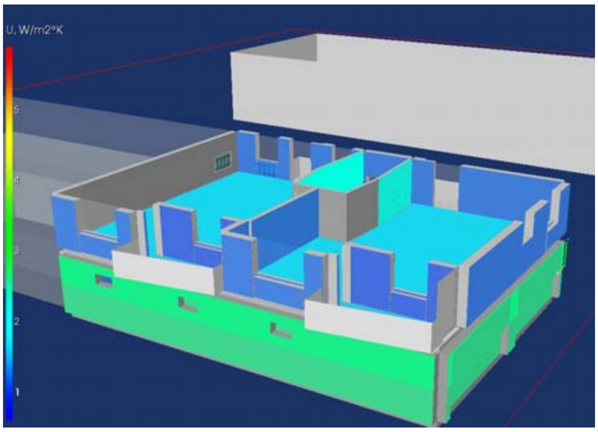
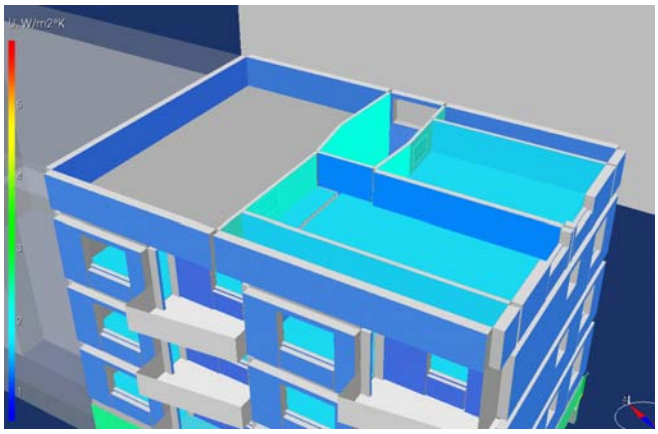
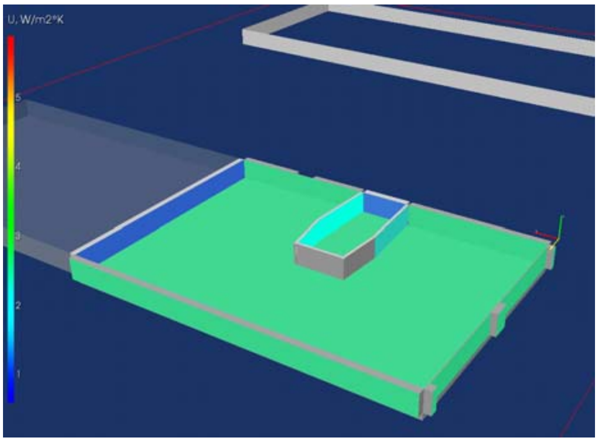
W/(m2*K)
Thickness
0.225
m
Layers
Floor top/Wall inside
Add
Delete
Roof tiles, 0.05 m
Horizontal cavity, 0.12 m
Mineral wool, 0.04 m
Fir wood, 0.015 m
Floor bottom/Wall outside
Layer data
Material
Roof tiles
Thickness
0.05
m
OK
Save as...
Cancel
Help

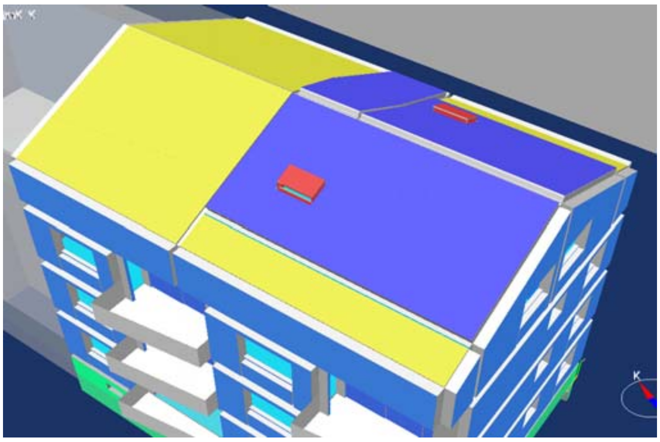

Wall definition
Wall definition
Roof above unheated attic space
Description
U-value
4.545
W/(m2*K)
Thickness
0.05
m
Layers
Floor top/Wall inside
Add
Delete
Roof tiles, 0.05 m
Floor bottom/Wall outside
Layer data
Material
Roof tiles
Thickness
0.05
m
OK
Save as...
Cancel
Help

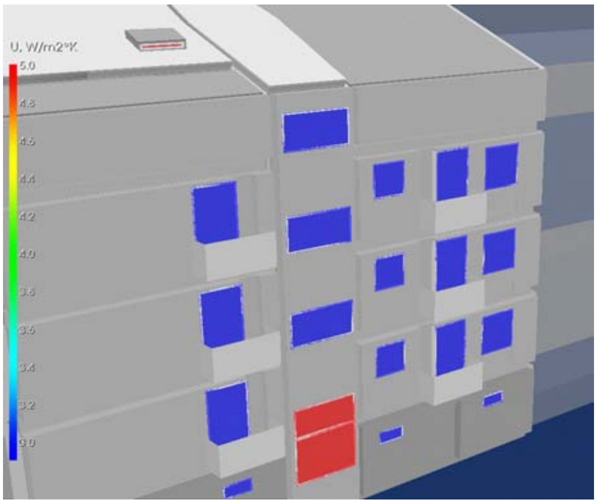

Wall definition
Wall definition
MetallicRoof
Description
U-value
5.874
W/(m2*K)
Thickness
0.05
m
Layers
Floor top/Wall inside
Add
Delete
Aluminium, 0.05 m
Floor bottom/Wall outside
Layer data
Material
Aluminium
Thickness
0.05
m
OK
Save as...
Cancel
Help

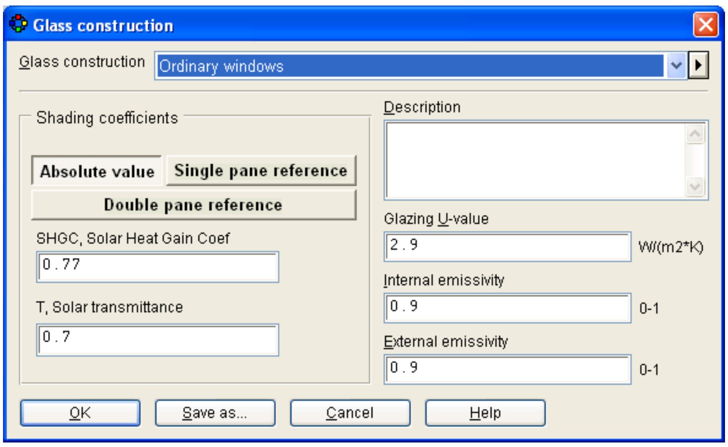

U, W/m2*K

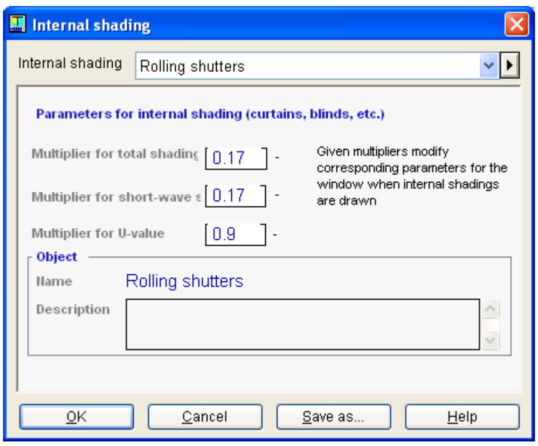

U, W/m2*K

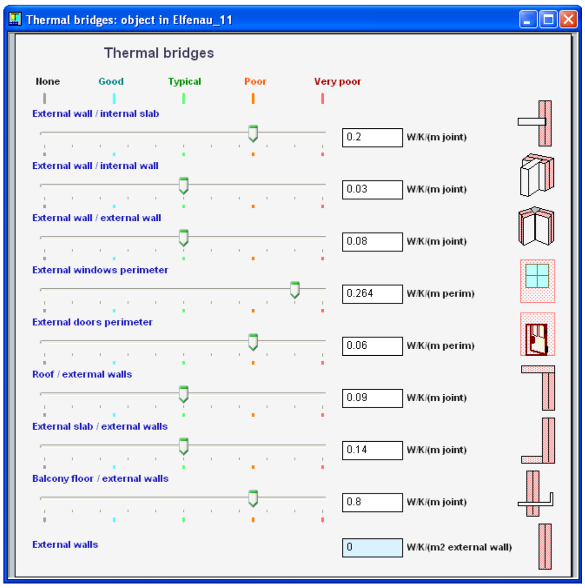

U, W/m2*K

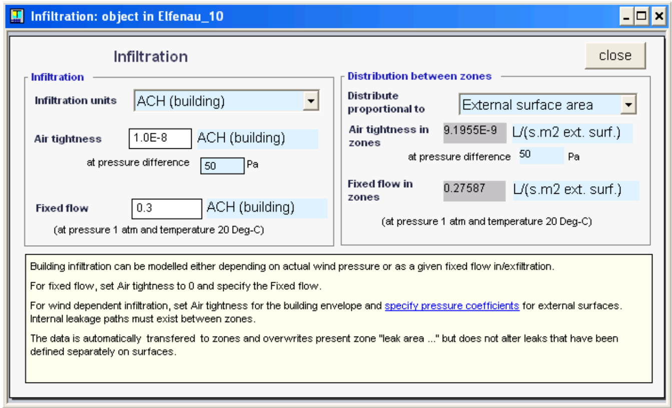



U, W/m2*K
5.0

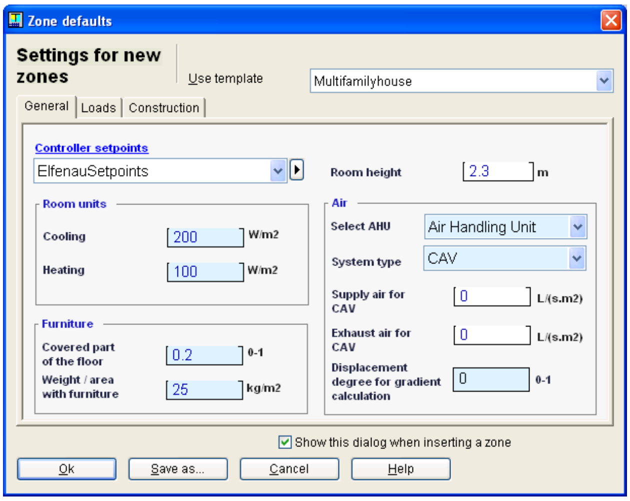

Glass construction
Glass construction
Ordinary windows
Shading coefficients
Absolute value
Single pane reference
Double pane reference
SHGC, Solar Heat Gain Coef
0.77
T, Solar transmittance
0.7
Description
Glazing U-value
2.9
W/(m2*K)
Internal emissivity
0.9
0-1
External emissivity
0.9
0-1
OK
Save as...
Cancel
Help

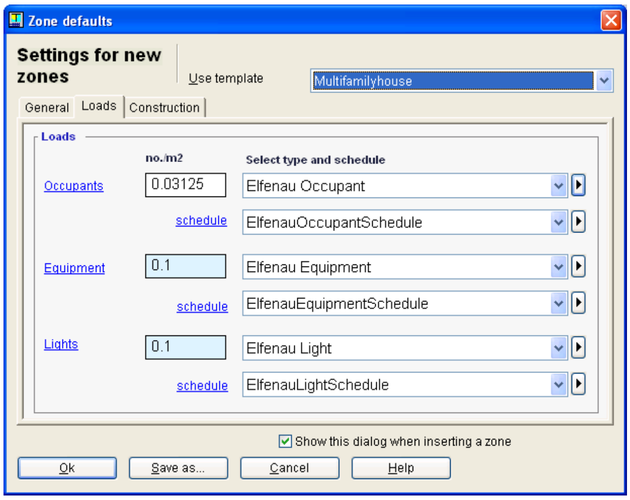

Internal shading
Internal shading
Rolling shutters
Parameters for internal shading (curtains, blinds, etc.)
Multiplier for total shading
0.17
Multiplier for short-wave
0.17
Multiplier for U-value
0.9
Given multipliers modify corresponding parameters for the window when internal shadings are drawn
Object
Name
Rolling shutters
Description
OK
Cancel
Save as...
Help

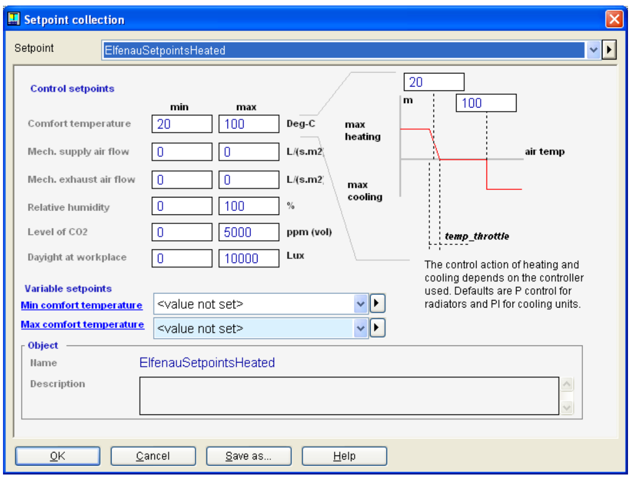


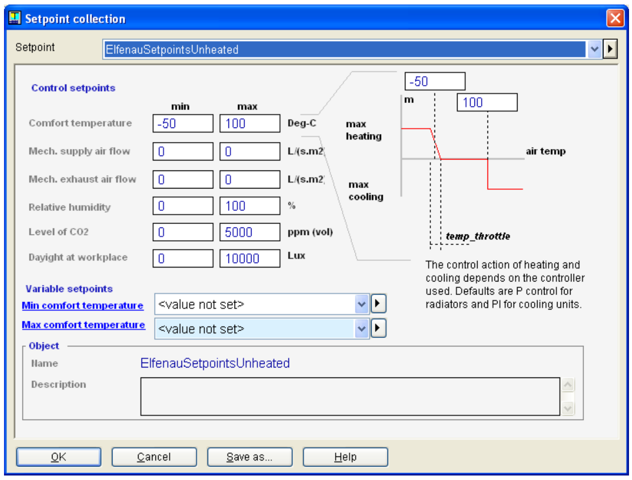


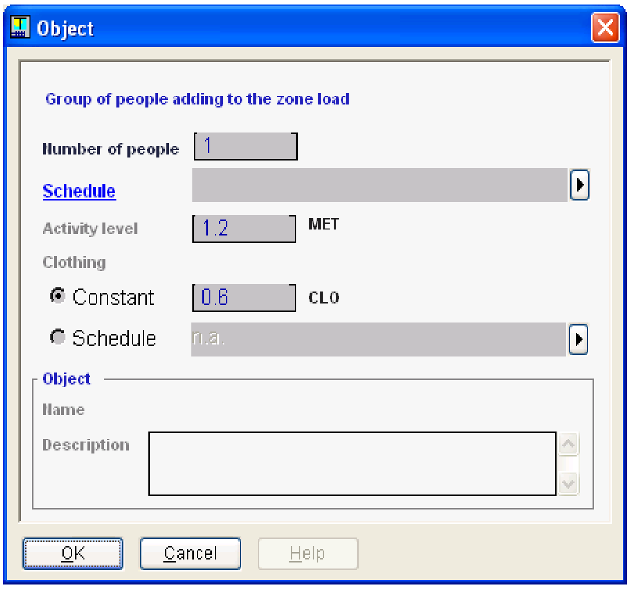
3. Building Use

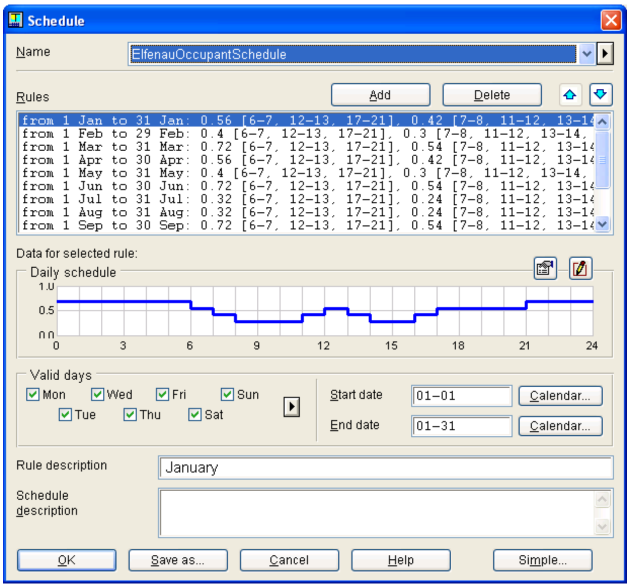


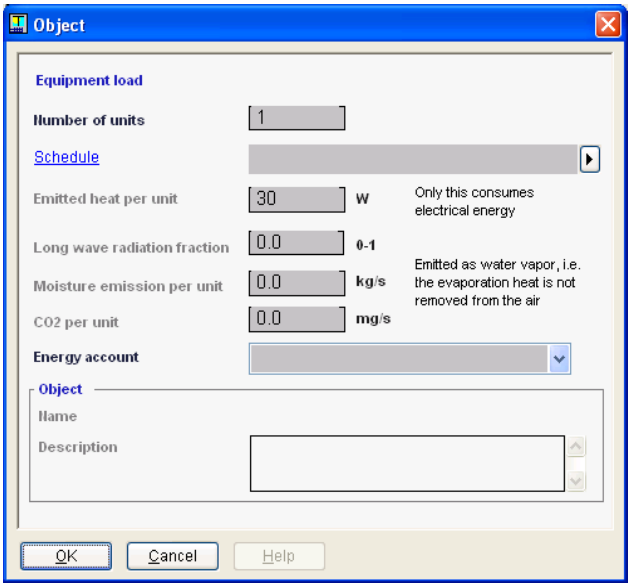


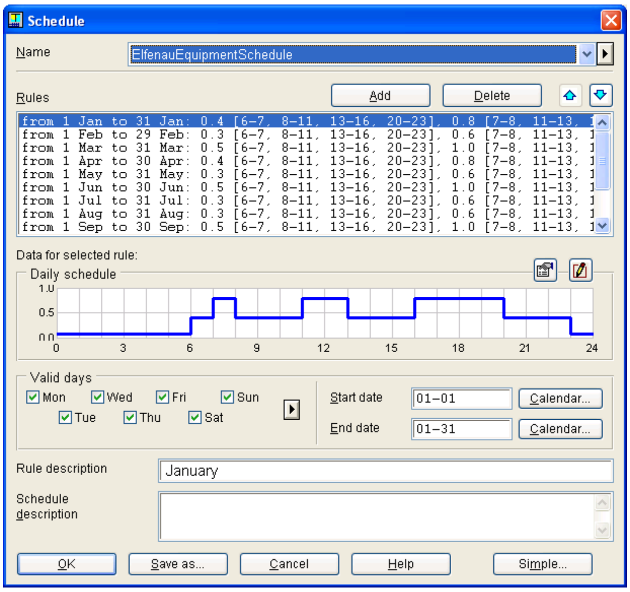


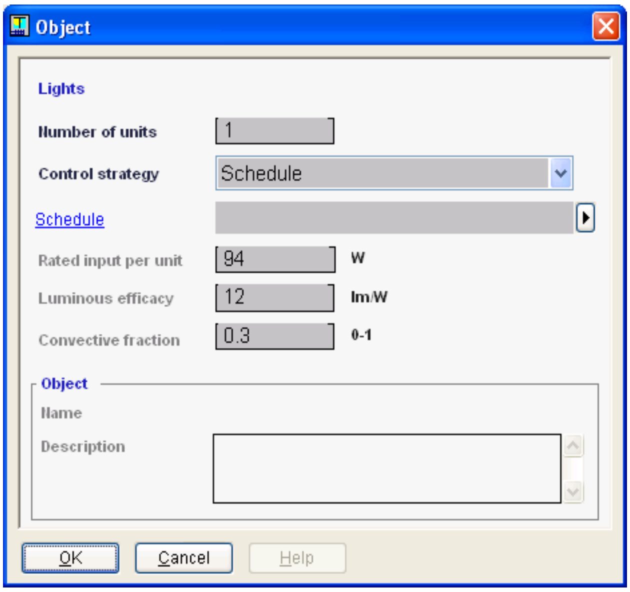


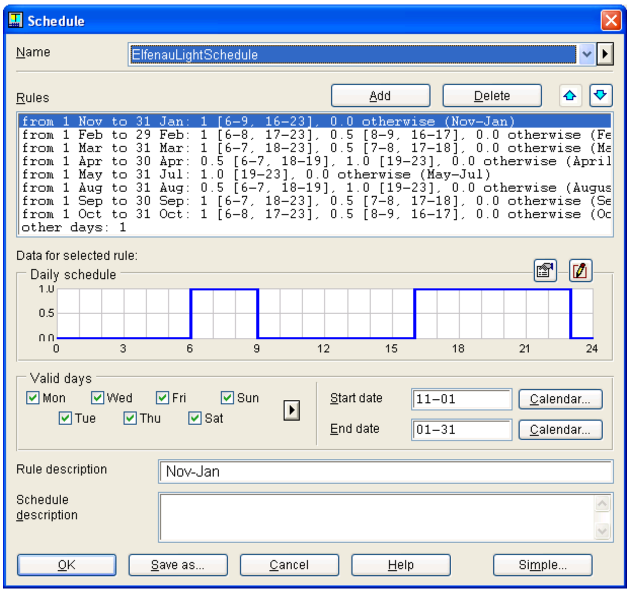

Object
Group of people adding to the zone load
Number of people 1
Schedule
Activity level 1.2 MET
Clothing
Constant 0.6 CLO
Schedule n.a.
Object
Name
Description
OK Cancel Help


Schedule
Name ElfenauOccupantSchedule
Rules Add Delete
from 1 Jan to 31 Jan: 0.56 [6-7, 12-13, 17-21], 0.42 [7-8, 11-12, 13-1
from 1 Feb to 29 Feb: 0.4 [6-7, 12-13, 17-21], 0.3 [7-8, 11-12, 13-14,
from 1 Mar to 31 Mar: 0.72 [6-7, 12-13, 17-21], 0.54 [7-8, 11-12, 13-1
from 1 Apr to 30 Apr: 0.56 [6-7, 12-13, 17-21], 0.42 [7-8, 11-12, 13-1
from 1 May to 31 May: 0.4 [6-7, 12-13, 17-21], 0.3 [7-8, 11-12, 13-14,
from 1 Jun to 30 Jun: 0.72 [6-7, 12-13, 17-21], 0.54 [7-8, 11-12, 13-1
from 1 Jul to 31 Jul: 0.32 [6-7, 12-13, 17-21], 0.24 [7-8, 11-12, 13-1
from 1 Aug to 31 Aug: 0.32 [6-7, 12-13, 17-21], 0.24 [7-8, 11-12, 13-1
from 1 Sep to 30 Sep: 0.72 [6-7, 12-13, 17-21], 0.54 [7-8, 11-12, 13-1
Data for selected rule:
Daily schedule
1.0 0.5 0.0
0 3 6 9 12 15 18 21 24
Valid days
Mon Wed Fri Sun
Tue Thu Sat
Start date 01-01 Calendar...
End date 01-31 Calendar...
Rule description January
Schedule description
OK Save as... Cancel Help Simple...


Object
Equipment load
Number of units 1
Schedule
Emitted heat per unit 30 W
Only this consumes electrical energy
Long wave radiation fraction 0.0 0-1
Moisture emission per unit 0.0 kg/s
Emitted as water vapor, i.e. the evaporation heat is not removed from the air
CO2 per unit 0.0 mg/s
Energy account
Object
Name
Description
OK Cancel Help


Schedule
Name ElfenauEquipmentSchedule
Rules Add Delete
from 1 Jan to 31 Jan: 0.4 [6-7, 8-11, 13-16, 20-23], 0.8 [7-8, 11-13, 1
from 1 Feb to 29 Feb: 0.3 [6-7, 8-11, 13-16, 20-23], 0.6 [7-8, 11-13, 1
from 1 Mar to 31 Mar: 0.5 [6-7, 8-11, 13-16, 20-23], 1.0 [7-8, 11-13, 1
from 1 Apr to 30 Apr: 0.4 [6-7, 8-11, 13-16, 20-23], 0.8 [7-8, 11-13, 1
from 1 May to 31 May: 0.3 [6-7, 8-11, 13-16, 20-23], 0.6 [7-8, 11-13, 1
from 1 Jun to 30 Jun: 0.5 [6-7, 8-11, 13-16, 20-23], 1.0 [7-8, 11-13, 1
from 1 Jul to 31 Jul: 0.3 [6-7, 8-11, 13-16, 20-23], 0.6 [7-8, 11-13, 1
from 1 Aug to 31 Aug: 0.3 [6-7, 8-11, 13-16, 20-23], 0.6 [7-8, 11-13, 1
from 1 Sep to 30 Sep: 0.5 [6-7, 8-11, 13-16, 20-23], 1.0 [7-8, 11-13, 1
Data for selected rule:
Daily schedule
1.0 0.5 0.0
0 3 6 9 12 15 18 21 24
Valid days
Mon Wed Fri Sun
Tue Thu Sat
Start date 01-01 Calendar...
End date 01-31 Calendar...
Rule description January
Schedule description
OK Save as... Cancel Help Simple...


Object
Lights
Number of units 1
Control strategy Schedule
Schedule
Rated input per unit 94 W
Luminous efficacy 12 lm/W
Convective fraction 0.3 0-1
Object
Name
Description
OK Cancel Help

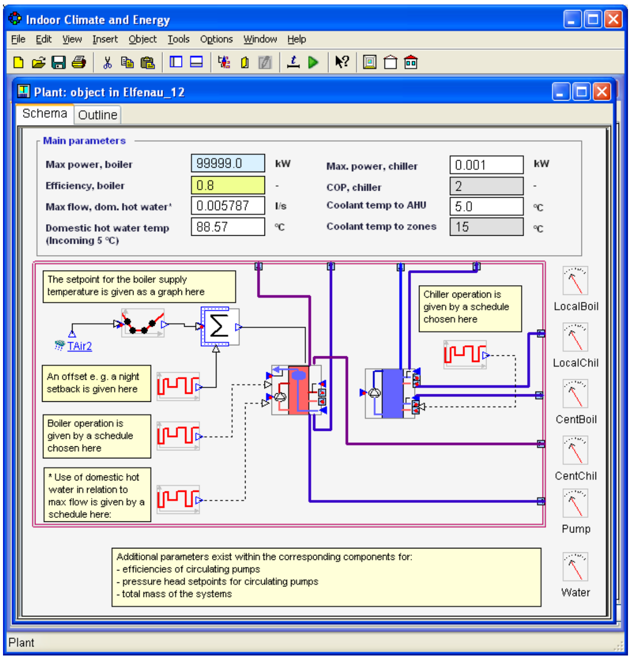

Schedule
Name ElfenauLightSchedule
Rules Add Delete
from 1 Nov to 31 Jan: 1 [6-9, 16-23], 0.0 otherwise (Nov-Jan)
from 1 Feb to 29 Feb: 1 [6-8, 17-23], 0.5 [8-9, 16-17], 0.0 otherwise (Fe
from 1 Mar to 31 Mar: 1 [6-7, 18-23], 0.5 [7-8, 17-18], 0.0 otherwise (Ma
from 1 Apr to 30 Apr: 0.5 [6-7, 18-19], 1.0 [19-23], 0.0 otherwise (April
from 1 May to 31 Jul: 1.0 [19-23], 0.0 otherwise (May-Jul)
from 1 Aug to 31 Aug: 0.5 [6-7, 18-19], 1.0 [19-23], 0.0 otherwise (Augus
from 1 Sep to 30 Sep: 1 [6-7, 18-23], 0.5 [7-8, 17-18], 0.0 otherwise (Se
from 1 Oct to 31 Oct: 1 [6-8, 17-23], 0.5 [8-9, 16-17], 0.0 otherwise (Oc
other days: 1
Data for selected rule:
Daily schedule
1.0 0.5 0.0
0 3 6 9 12 15 18 21 24
Valid days
Mon Wed Fri Sun
Tue Thu Sat
Start date 11-01 Calendar...
End date 01-31 Calendar...
Rule description Nov-Jan
Schedule description
OK Save as... Cancel Help Simple...

4. Domestic Hot Water

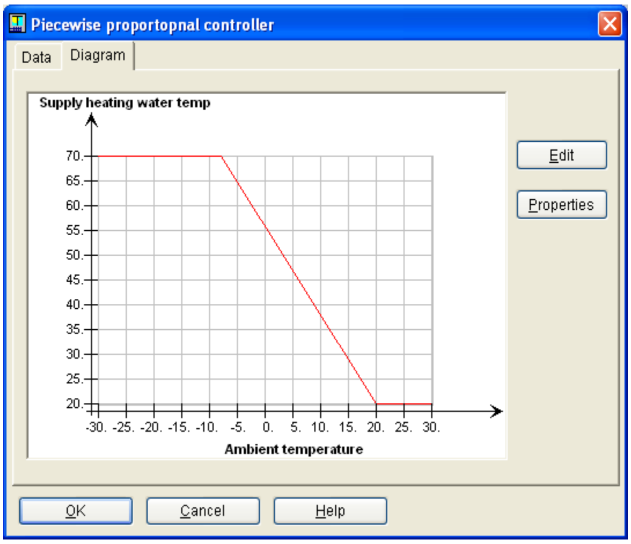
14 Persons in total using 35l/d each -> total hot water use = 500 l/d = 20.8 l/h = 0.005787 l/s

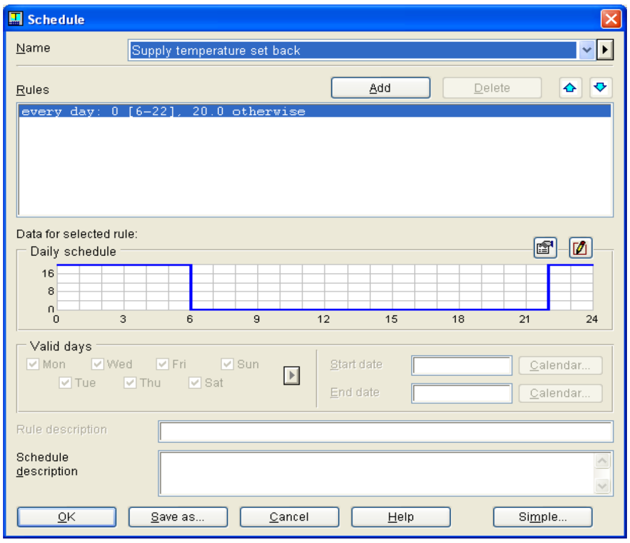
500 l/d = 182'500 l/year = 42 GJ/ year = 75 MJ/(m^2·y)

In order to take the water distribution efficiency of 0.7 into account, hot water level is set to 88.87 °C



5. Heating System



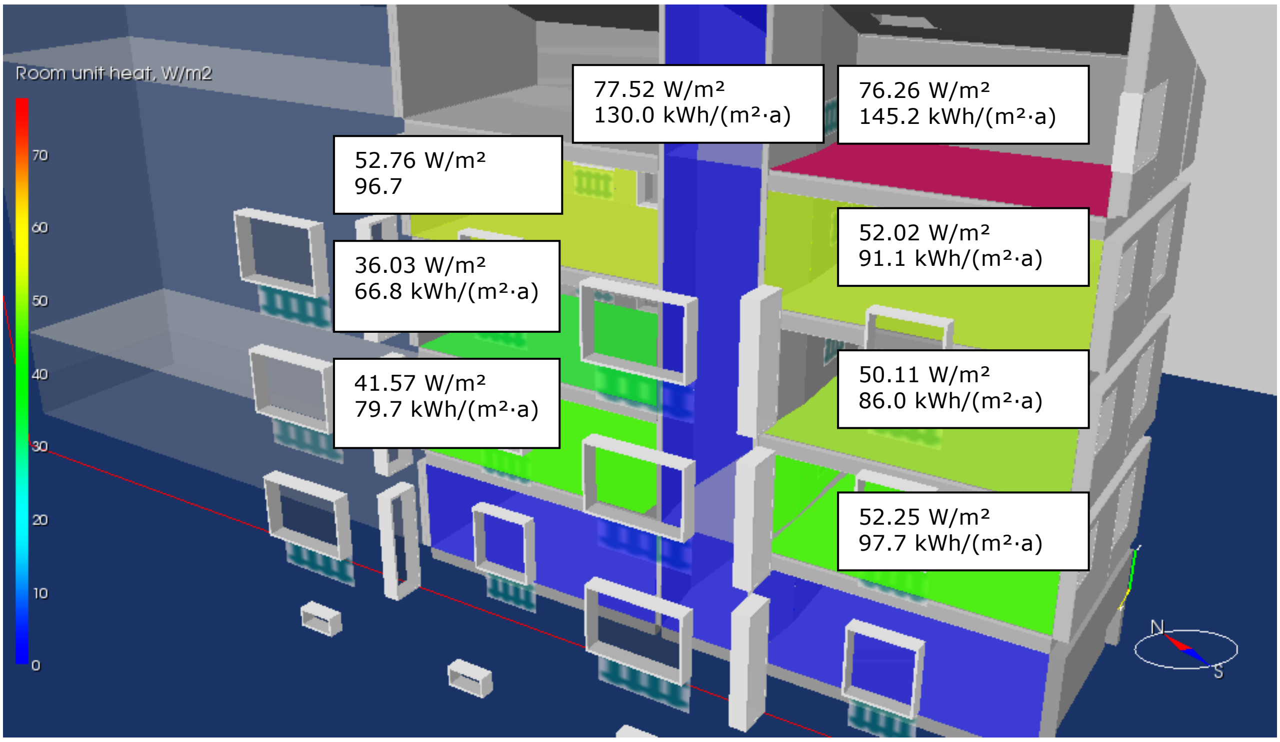


To set the max power of the radiators, an initial simulation was done for the winter design day (-5.95 ... -10.4 °C) with 10 kW max power for each radiator. The following table shows the results of the design day calculation and the set max power for cases 1.a and 1.b

Flat	Max power design day simulation [kW]	Set max power case 1.a [kW]	Set max power case 1.b [kW]
Ground floor SE	3.5	4 x 1.0	4 x 2.0
Ground floor NW	2.6	4 x 1.0	4 x 2.0
1st floor SE	3.0	4 x 1.0	4 x 2.0
1st floor NW	2.3	4 x 1.0	4 x 2.0
2nd floor SE	3.2	4 x 1.0	4 x 2.0
2nd floor NW	3.3	4 x 1.0	4 x 2.0
Attic SW	2.1	2 x 1.5	2 x 2.0
Attic NE	1.7	2 x 1.5	2 x 2.0

6. Results

6.1. Case 1.a (low max heating power)



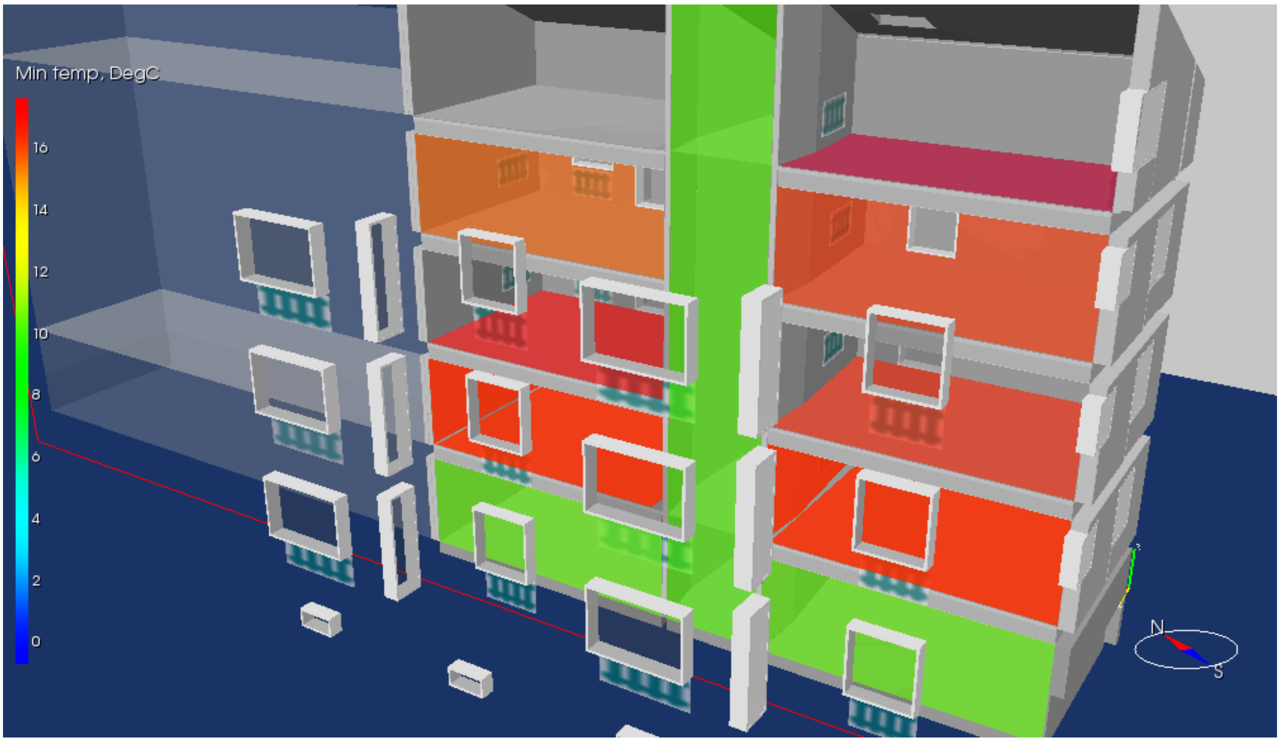
Heating demand (max power and yearly energy)

Case 1.a

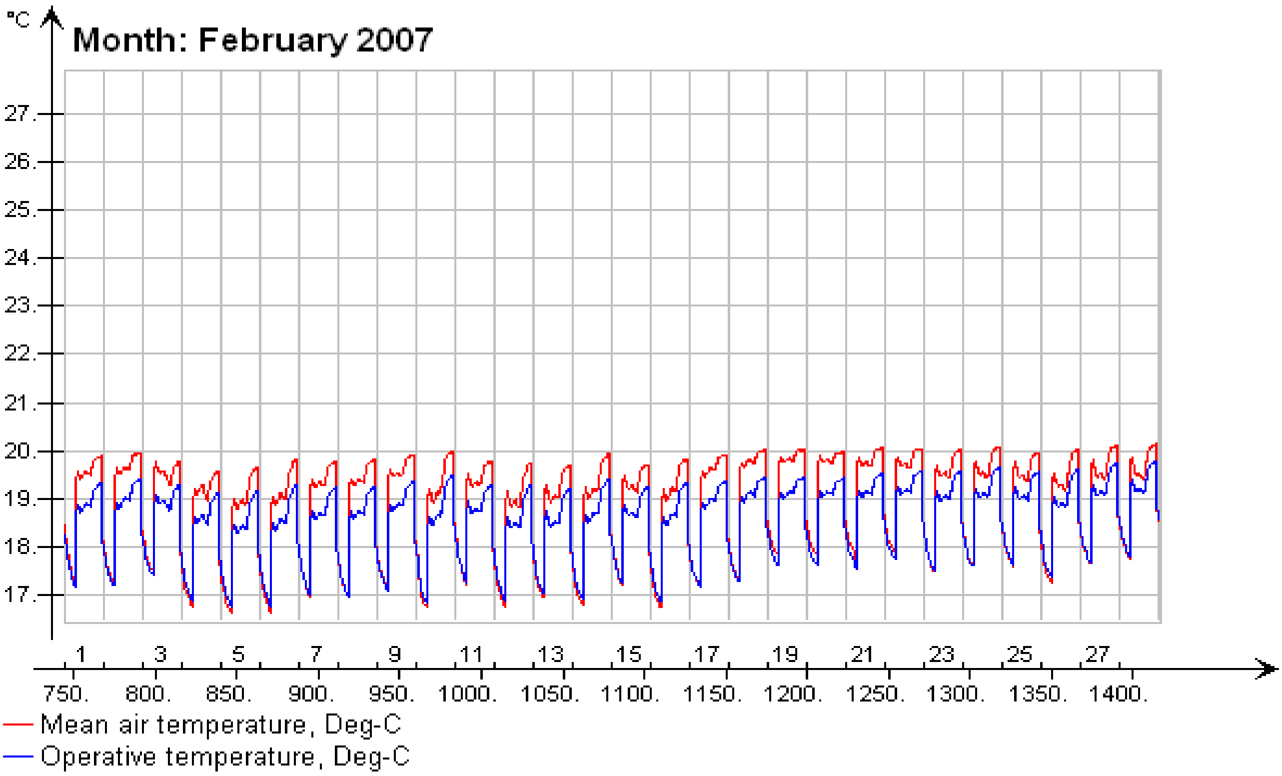
From radiators to Zone	Area, m^2	kWh/a	kWh/(m^2·y)
Ground floor_SE	69	6'750	97.7
Ground floor_NW	70	5'618	79.7
1st floor_SE	69	5'942	86.0
1st floor_NW	70	4'701	66.8
2nd floor_SE	69	6'290	91.1
2nd floor_NW	70	6'809	96.7
Attic SW	34	4'441	130.0
Attic NE	25	3'649	145.2

TOTAL to zones	478	44'200	92.5
Used for heating	565	49'968	88.4
Used for DHW	565	16'676	29.5
Used for both	565	66'646	118.0
Purchased for both	565	83'300	147.4

Energy demand for room heating and DHW

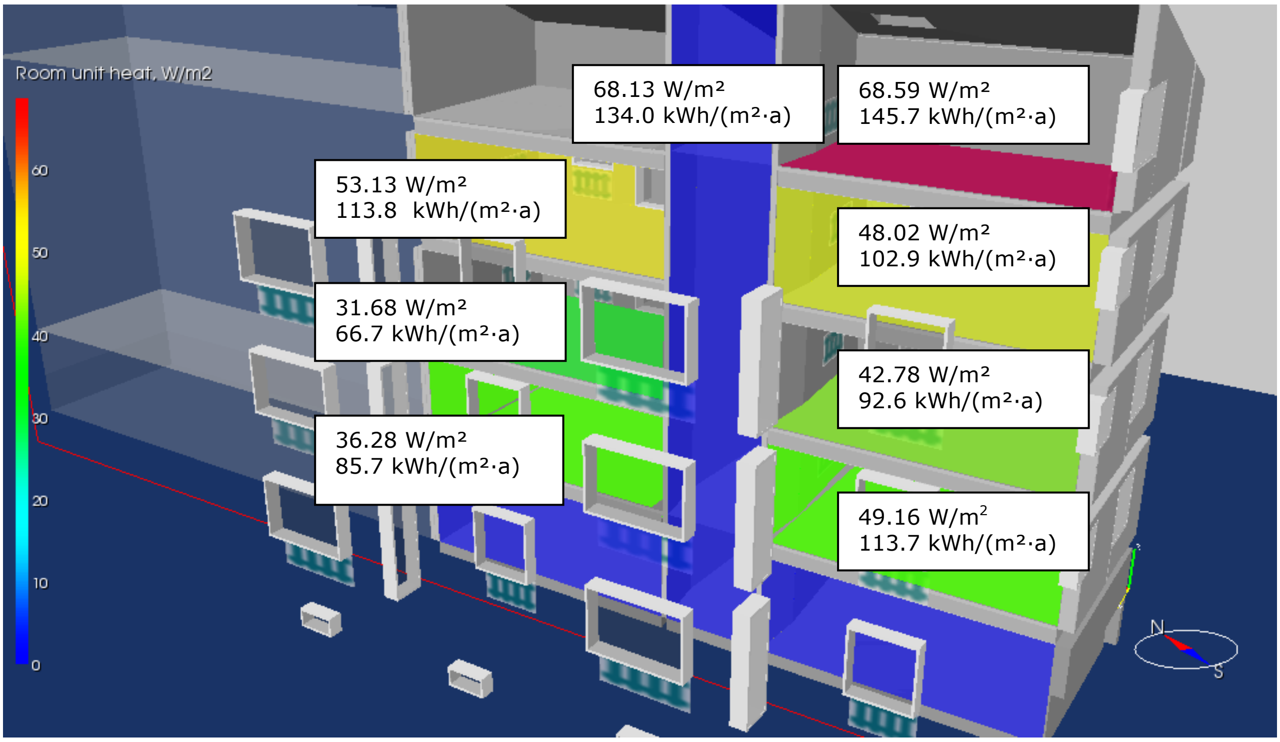


Min temperatures (night setback)



February temperatures in 1st floor SE

6.2. Case 1.b (double max heating power)

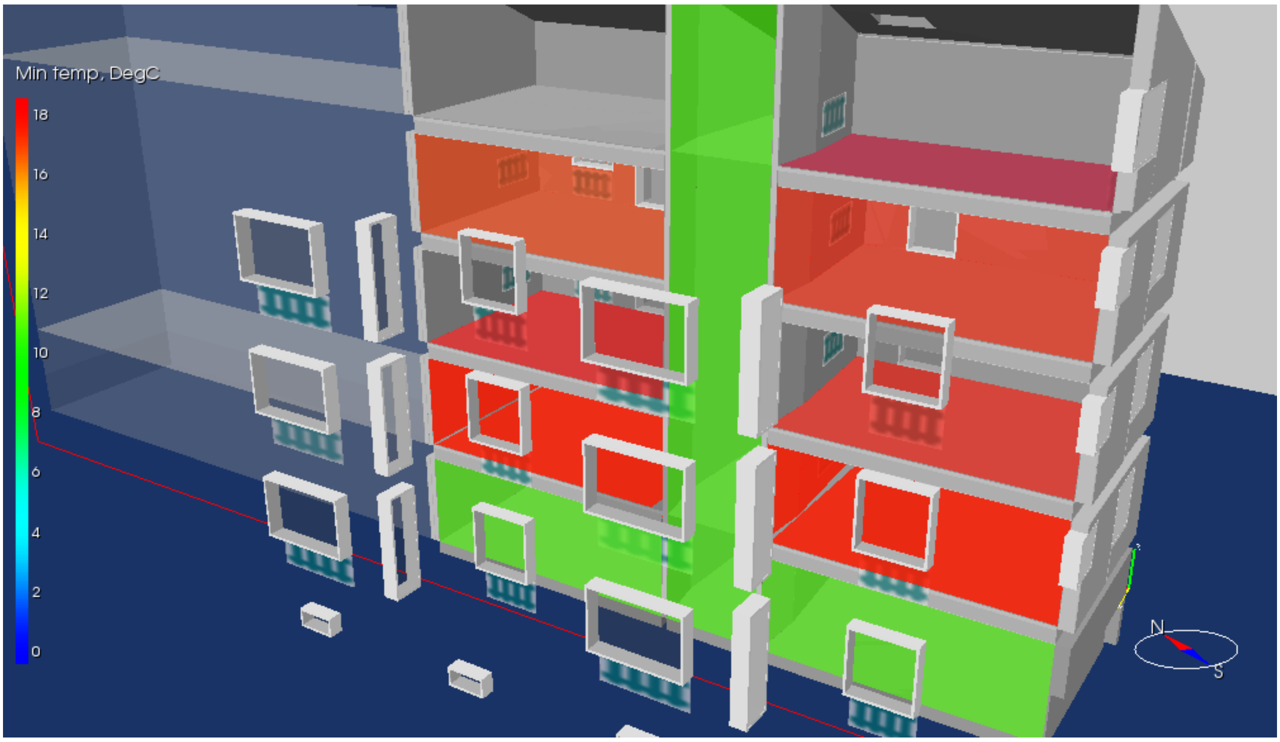


Heating demand (max power and yearly energy)

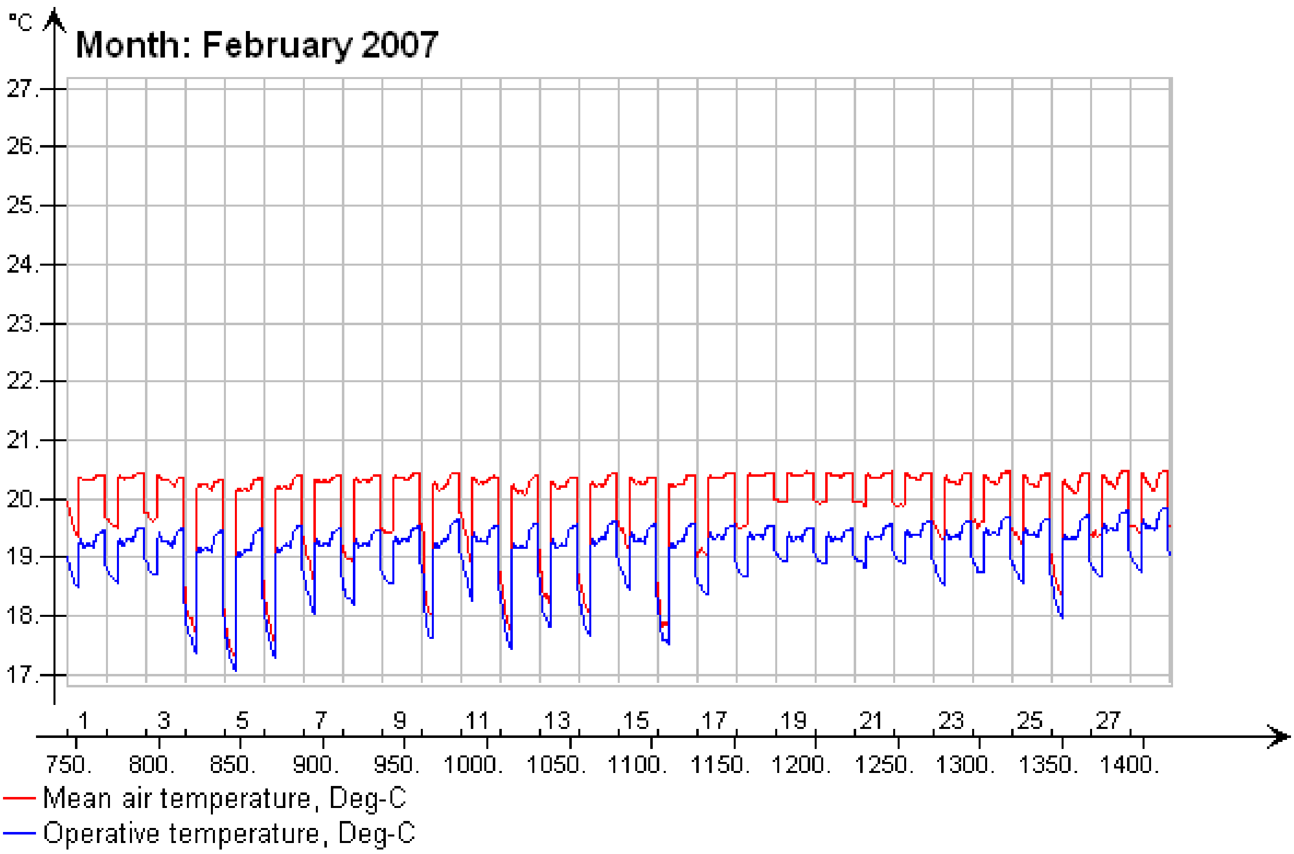
Case 1.b

From radiators to Zone	Area, m^2	kWh/a	kWh/(m^2·y)
Ground floor_SE	69	7'851	113.7
Ground floor_NW	70	6'045	85.7
1st floor_SE	69	6'398	92.6
1st floor_NW	70	4'698	66.7
2nd floor_SE	69	7'105	102.9
2ndfloor_NW	70	8'011	113.8
Attic SW	34	4'579	134.0
Attic NE	25	3'663	145.7
TOTAL to zones	**478**	**48'350**	**101.2**
Used for heating	**565**	**53'235**	**94.2**
Used for DHW	**565**	**16'675**	**29.5**
Used for both	**565**	**69'910**	**123.7**
Purchased for both	**565**	**87'390**	**154.7**

Energy demand for room heating and DHW



Min temperatures (night setback)



February temperatures in 1st floor SE

Appendix G
Step 1 and 2 Calculation report from University of Minho

Pedro Silva and Manuela Almeida, University of Minho

1. Introduction

The Cases 1 and 2 were simulated using the tool DesignBuilder to produce the model and the tool EnergyPlus to calculate the energy needs. Following this methodology we have calculated the useful and delivered energy needs.

As required, all the necessary inputs were the ones given to us in the Specifications Document and the climatic data necessary in case 1 was obtained using the data provided in order to contruct the file: Weather_Lucerne_EP.epw.

Case 2 corresponds to Guimarães, a Potuguese city located in the north of Portugal, 50 km away from the sea, and a climatic file was also constructed: Guimaraes04_UM_Dez03_3DOE2.epw

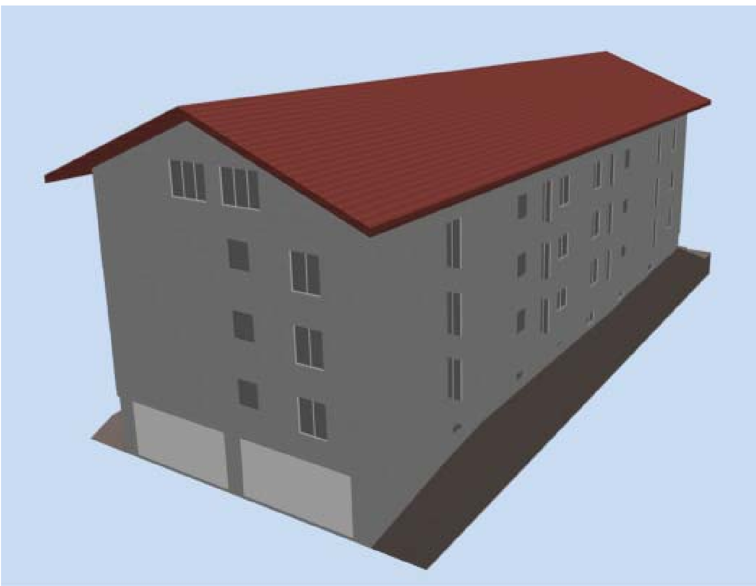
2. Calculation Procedures

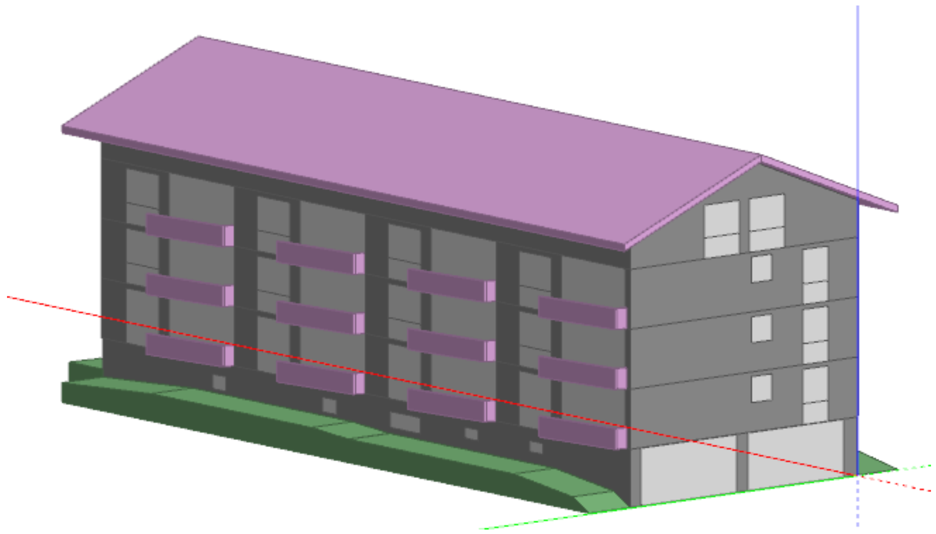
With all the model elements, construction and schedules introduced in the tool Design Builder, the building was simulated and a idf file was produced in order to apply it in EnergyPlus, however there were some simplifications:

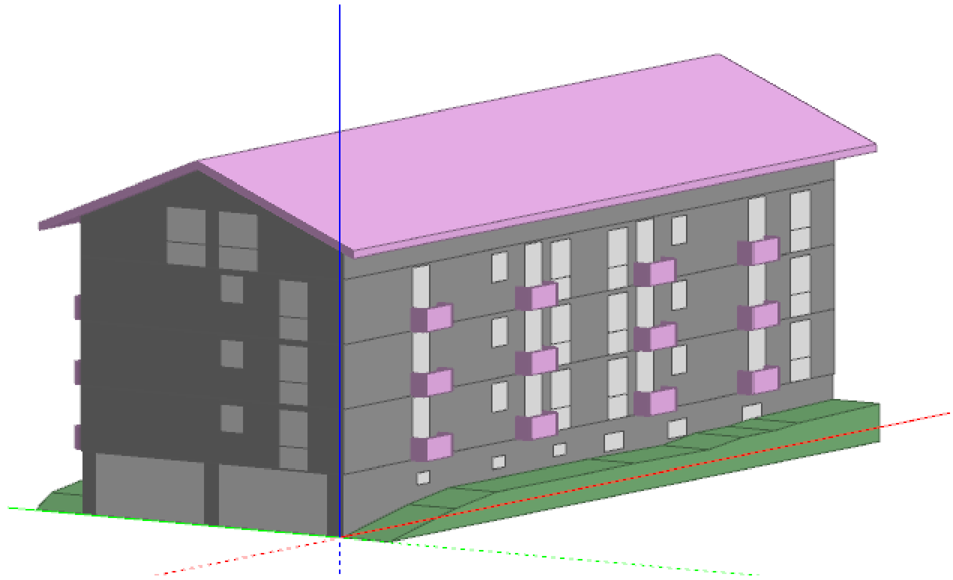
- The DHW was not defined correctly in this model but was obtained using the RCCTE (portuguese thermal regulation) methodology;
- The heating system was not introduced in the dynamic simulation, instead it was used the "Purchased Air" option in order to obtain the building energy needs, and after the necessary effiencies where applied in the excel worksheet.

3. Model Renders

To provide a more graphical demonstration of the "Lucerne" building model applied in the simulation, following there are several printscreens of the DesignBuilder model:







4. Results

Case study 1 (Lucerne)

		Heating	DHW	Total
Useful Energy Demand [kWh/(m²·y)]	B1	97.6	45.5	143.1
Primary Energy [kWh/(m²·y)]	B1	151.3	70.5	221.8

Case study 2 (Guimarães)

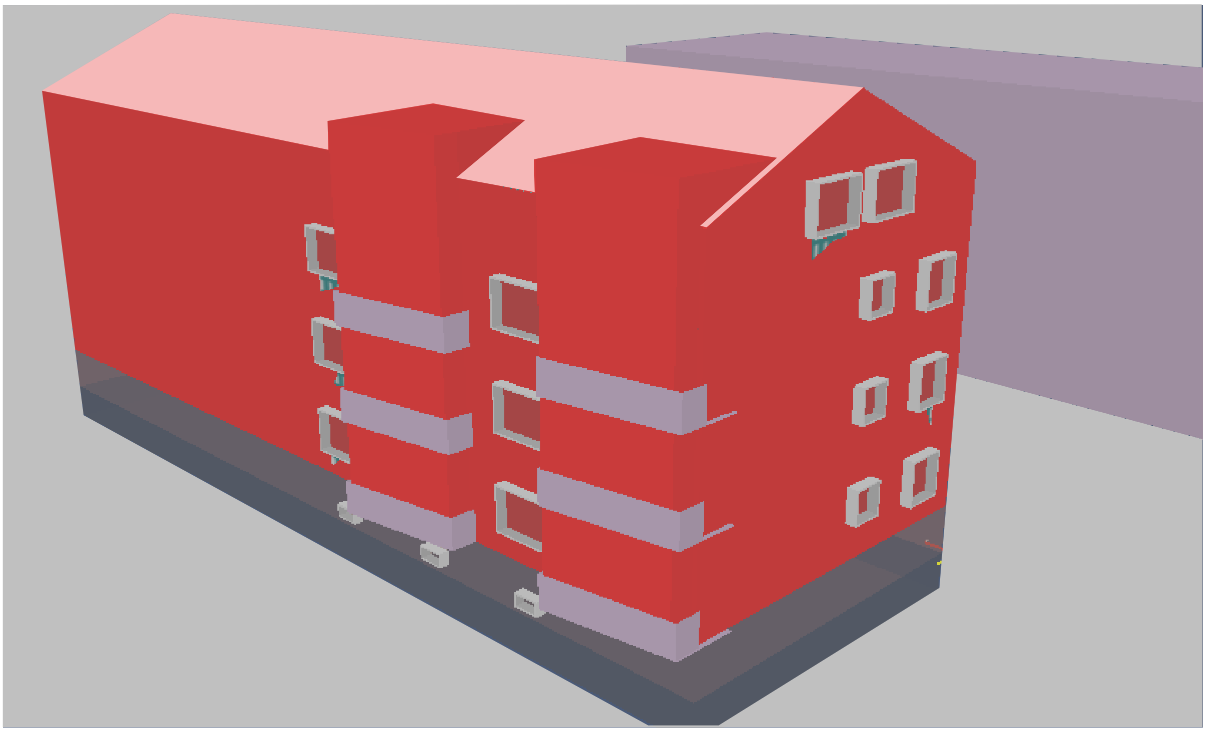
		Heating	DHW	Total
Useful Energy Demand [kWh/(m²·y)]	B1	17.5	45.5	63.0
Primary Energy [kWh/(m²·y)]	B1	27.2	70.5	97.7

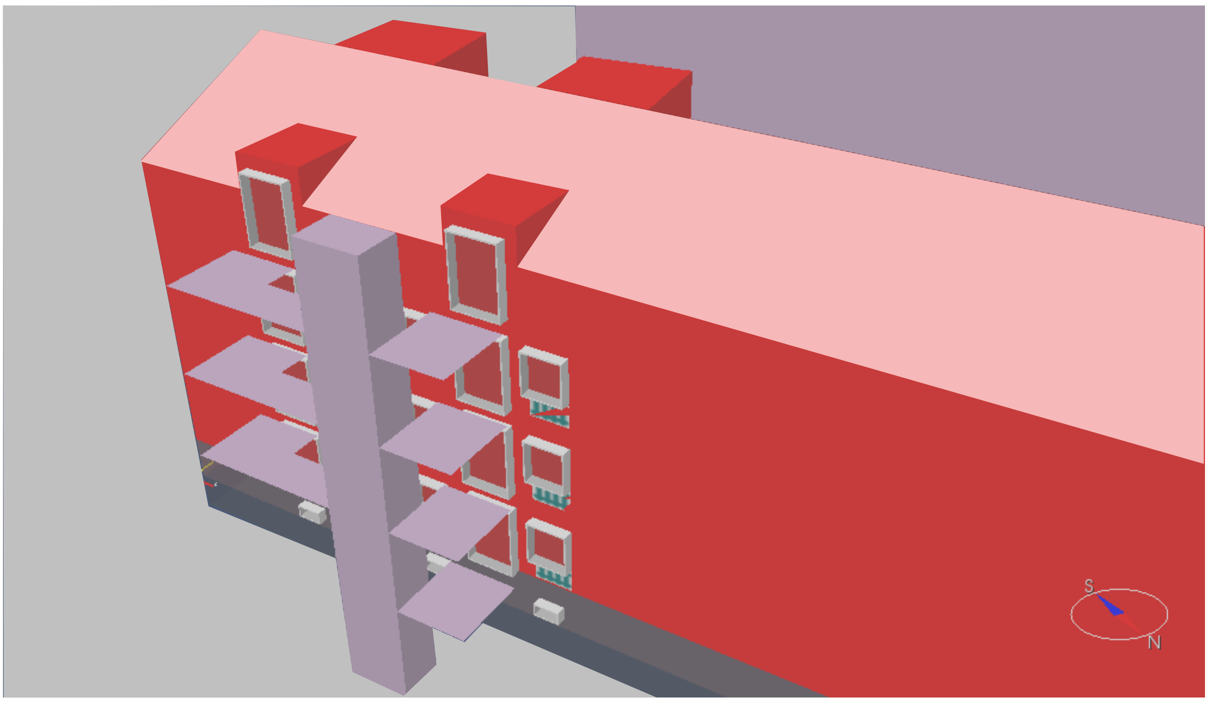
Appendix H
Step 3 Retrofit Case
Calculation Report for Swiss Location Lucerne

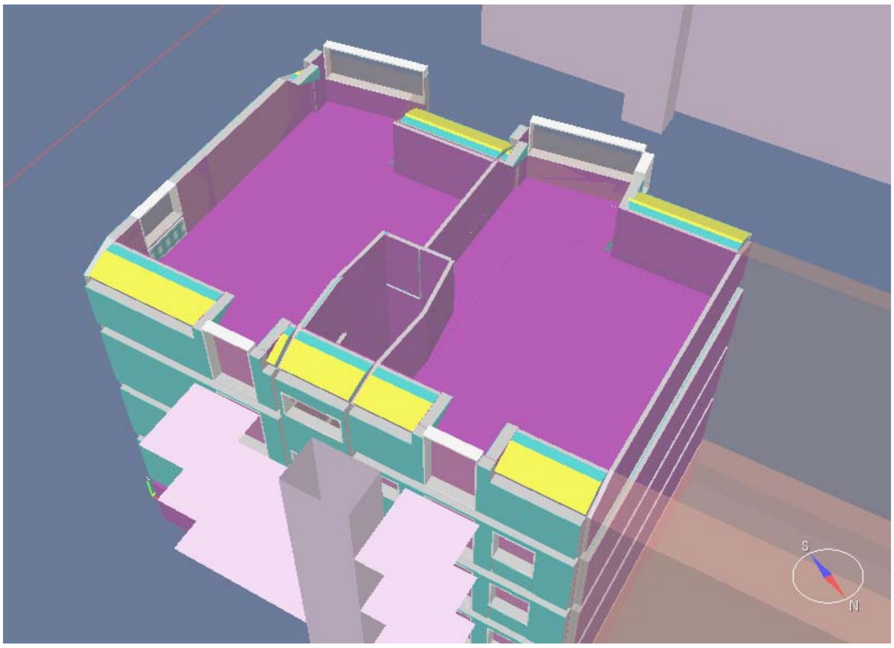
Sven Moosberger, Lucerne University of Applied Sciences and Arts (HSLU)

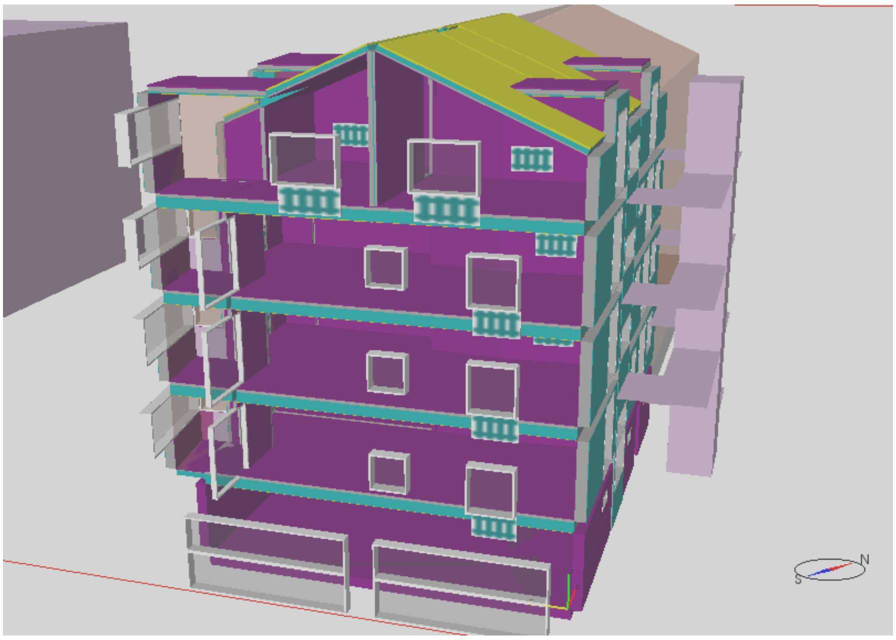
1. Building Changes

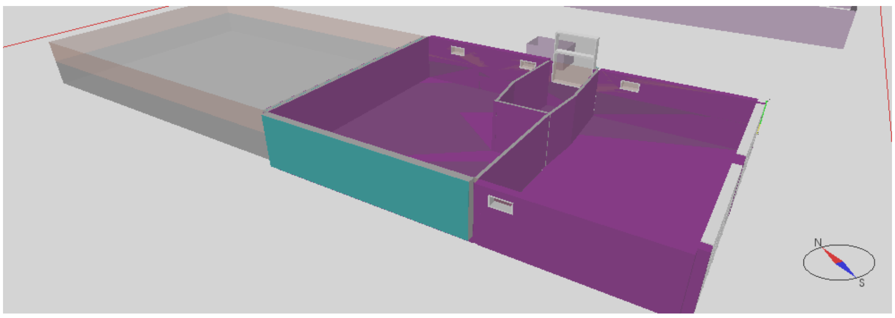
1.1. Geometry



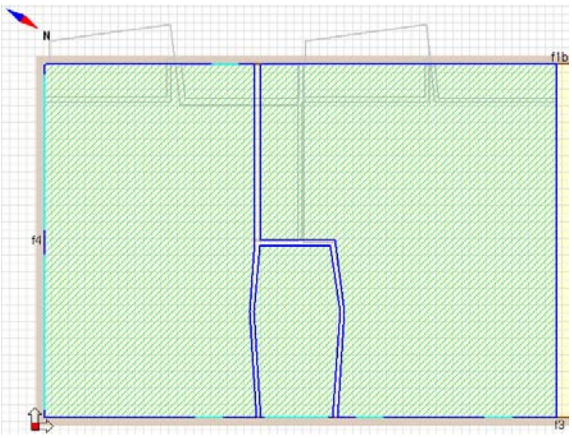


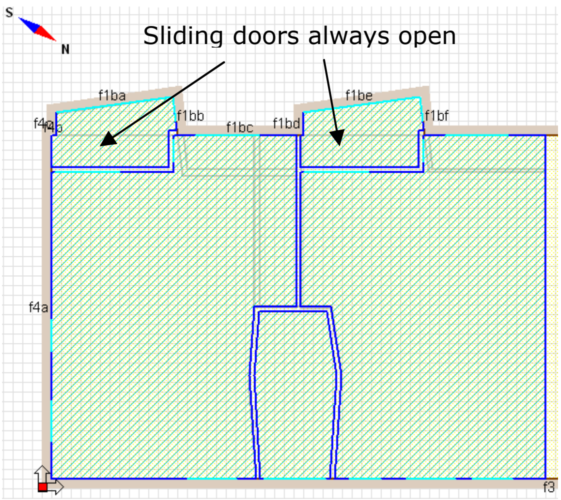


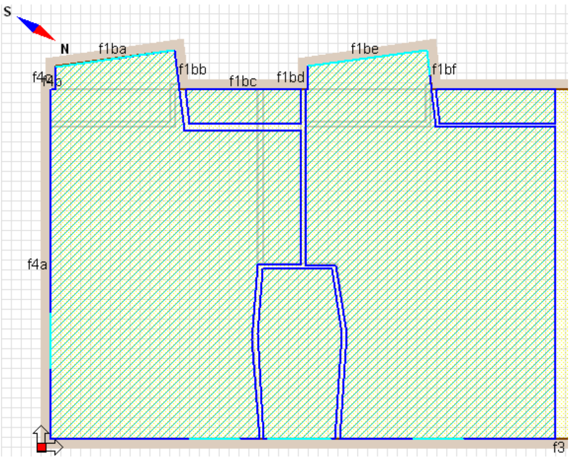




Name	Group	Area, m²
Stairhouse	unheated	5 x 12.15
Ground floor_SE	SE	69.07
Ground floor_NW	NW	70.50
Basement	unheated	81.49
1stfloor_SE	SE	69.07
1stfloor_NW	NW	70.41
2ndfloor_SE	SE	69.07
2ndfloor_NW	NW	70.41
Attic Store SW	unheated	3.63
Attic NW	Attic	74.01
Attic SW	Attic	72.32
Basement_Heated	Basement	66.52
Balcony Ground floor SE	Balconies	7.15
Balcony Ground floor NW	Balconies	7.17
Attic Store SW1	unheated	3.79
Balcony Ground floor SE1	Balconies	7.15
Balcony Ground floor NW1	Balconies	7.17
Balcony Ground floor SE2	Balconies	7.15
Balcony Ground floor NW2	Balconies	7.17
Building gross	incl. stairhouse	735.12
Net used area	excl. stairhouse	674.37



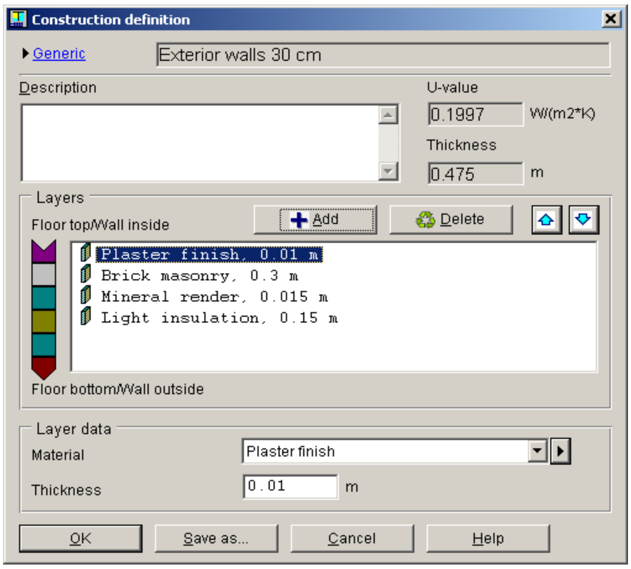


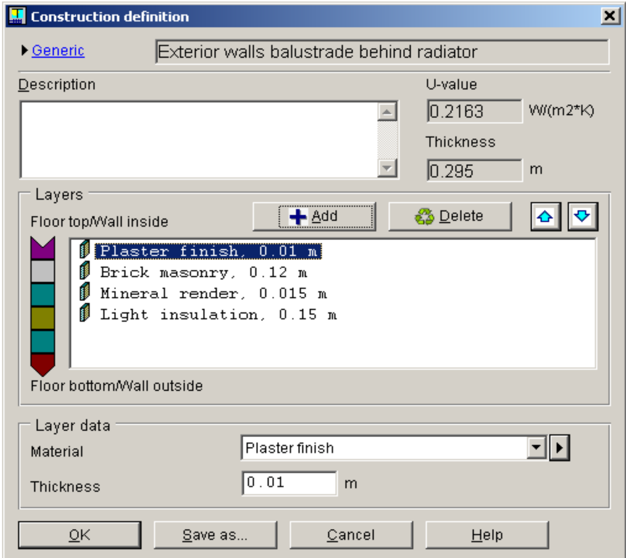


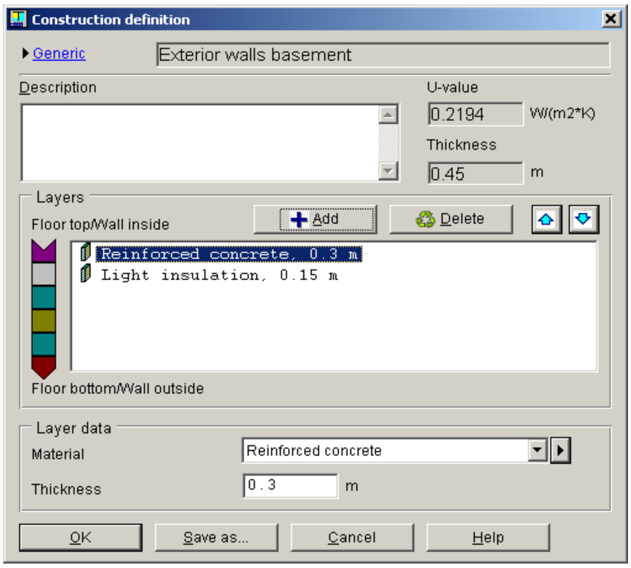
1.2. Constructions

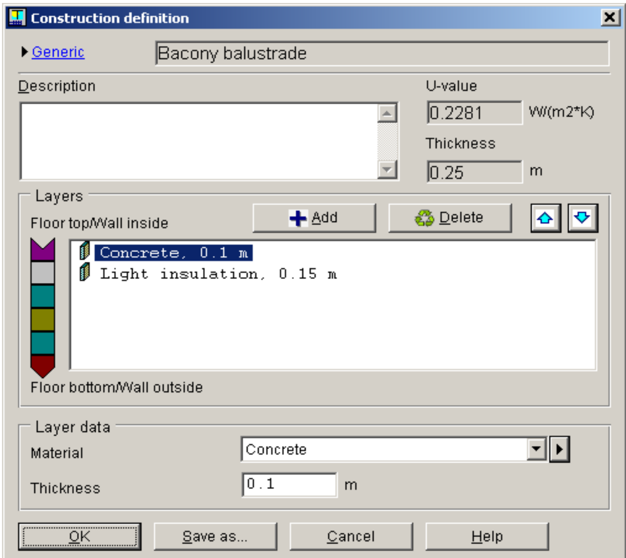
Case 3.a: additional insulation of 20 cm for external wall, 20 cm for retrofit modules and 20 cm for sloped roof. Glazing U = 0.5 W/(m^2·K).

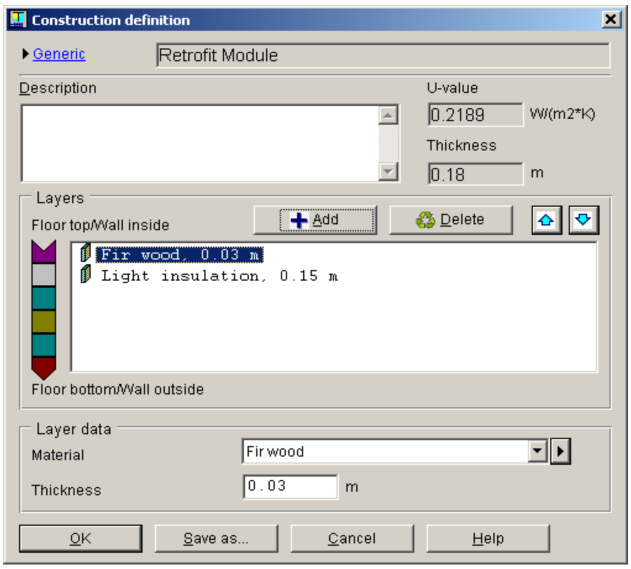
Case 3.b: additional insulation of 15 cm for external wall, 15 cm for retrofit modules and 20 cm for sloped roof. Glazing U = 0.6 W/(m^2·K)

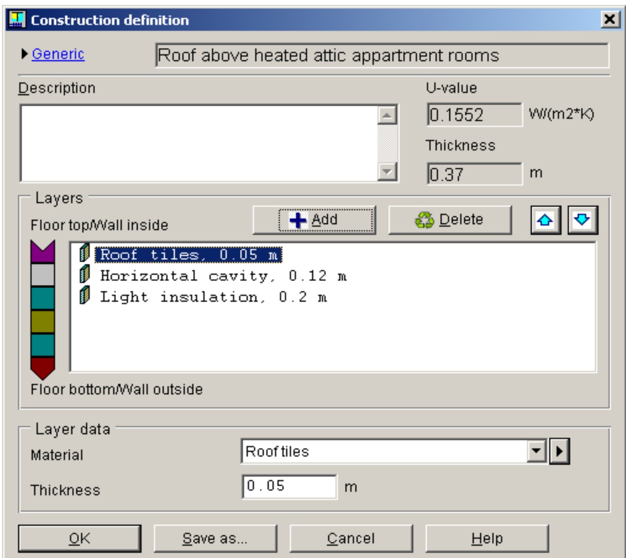


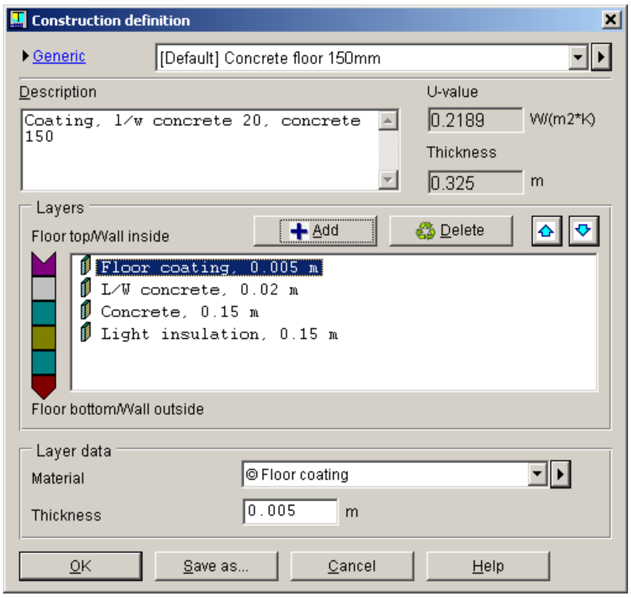


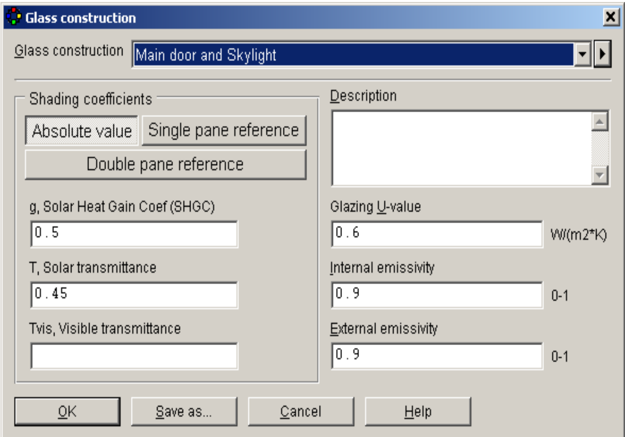


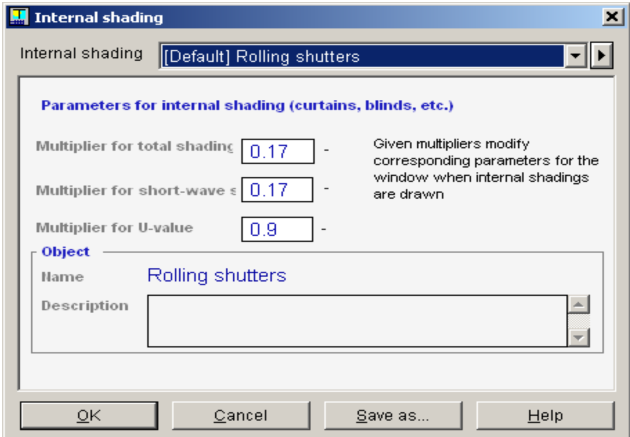












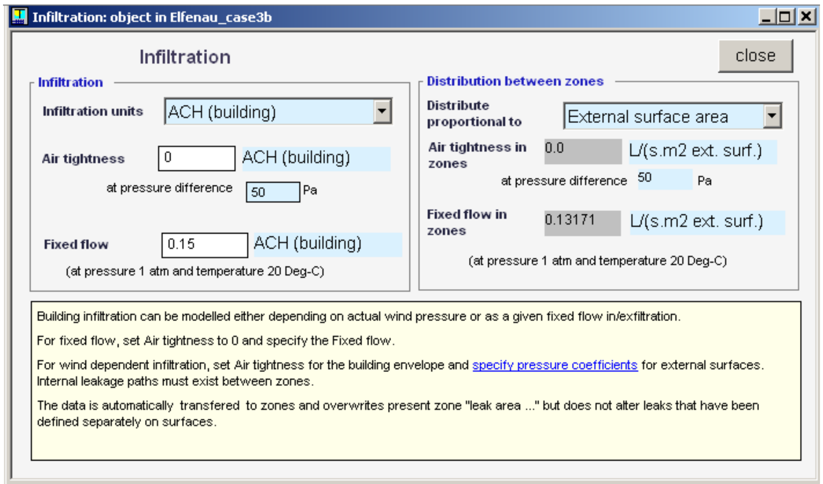
Rolling shutters are closed in summer (1st May – 30th September), when int. radiation > 50 W/m^2

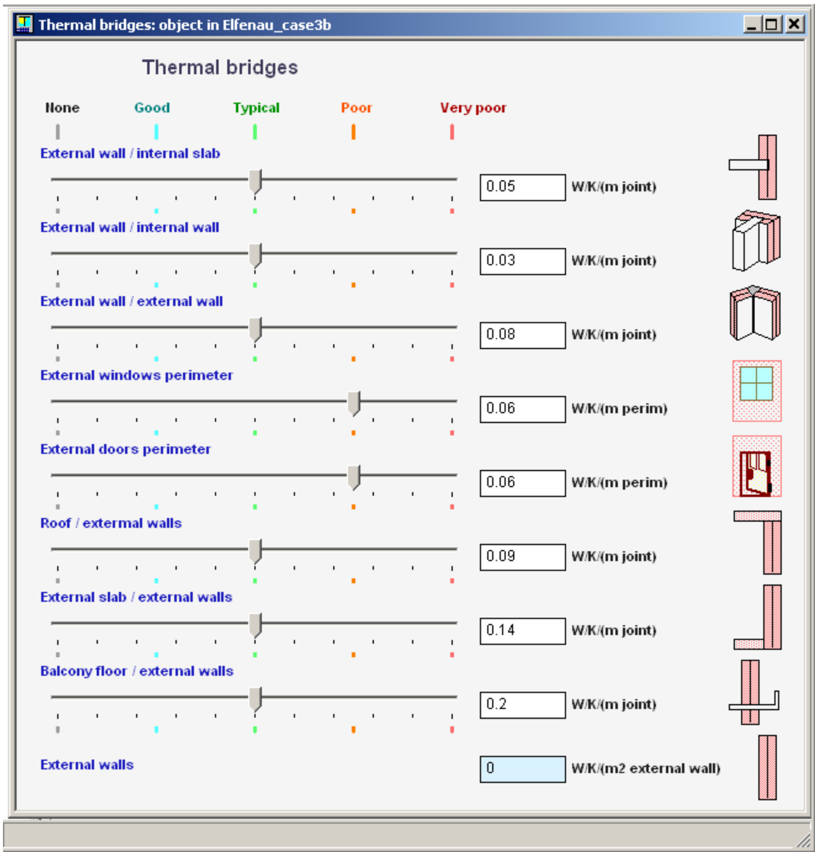
Case 3.c: additional insulation of 10 cm for external wall, 10 cm for retrofit modules and 12 cm for sloped roof. Glazing U= 0.7 W/(m^2·K).

Case 3.d: additional insulation of 5 cm for external wall, 5 cm for retrofit modules and 7 cm for sloped roof. Glazing U= 0.8 W/(m^2·K).

Case 3.e: no additional insulation for existing external constructions, 5 cm for retrofit. Glazing U= 0.8 W/(m^2·K).

1.3. Infiltration and thermal bridges



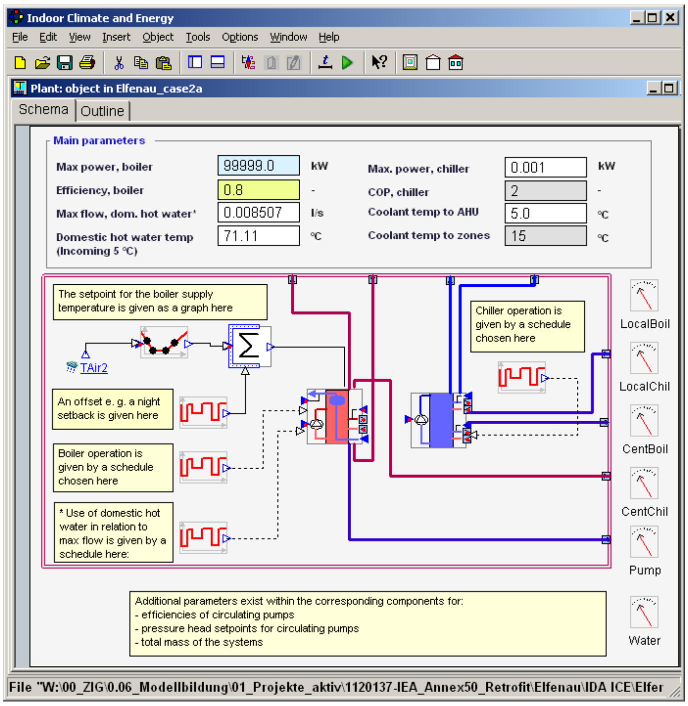


2. System changes

2.1. Domestic hot water

21 Persons in total using 35 l/d each -> total hot water use = 735 l/d = 30.6 l/h = 0.008507 l/s
735 l/d = 268’459 l/year = 62 GJ/year = 80 MJ/(m^2·y)

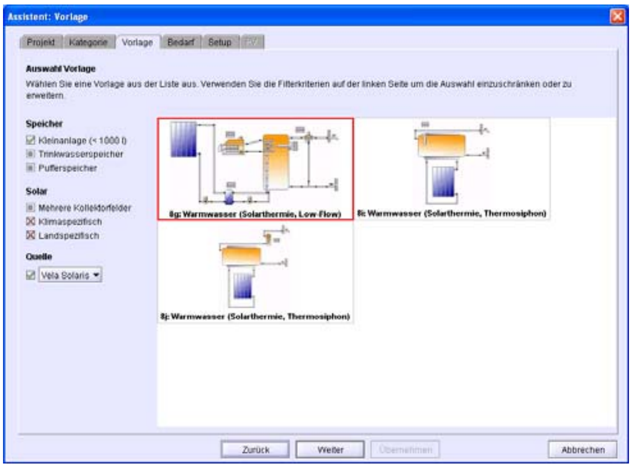
In order to take the water distribution efficiency of 0.9 into account, hot water level is set to 71.11

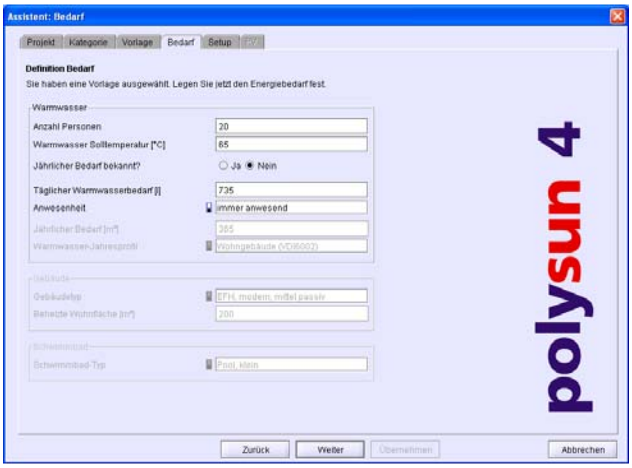


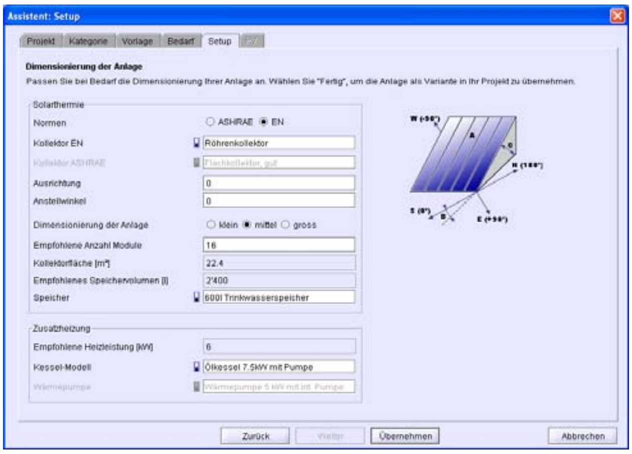
Solar contribution

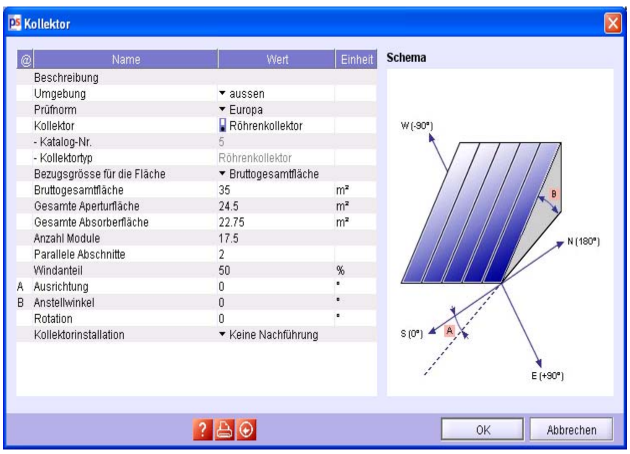
Vacuum tube collectors on all modules with flat roof:

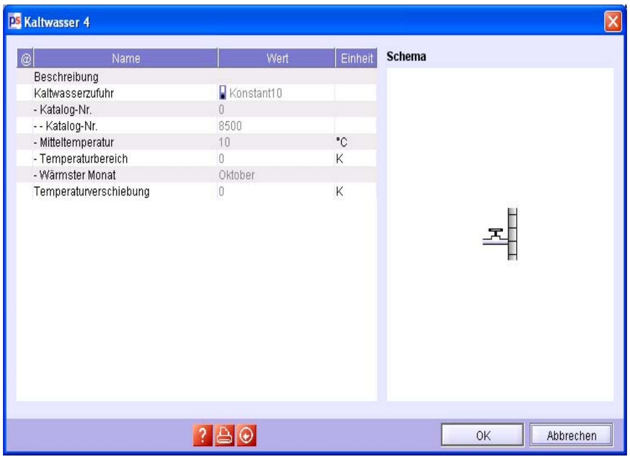
Simulation with Polysun

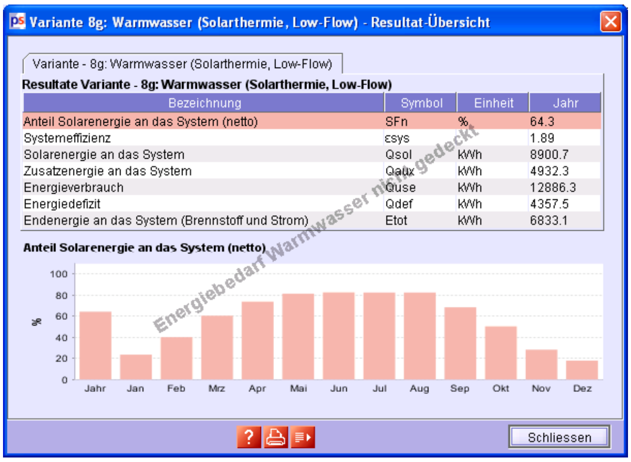








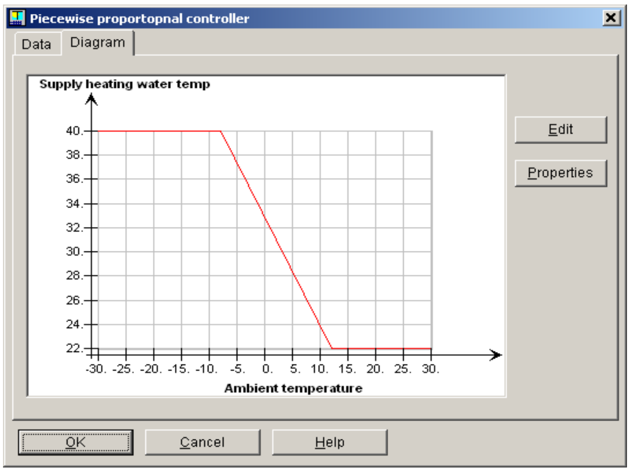




-> solar contribution to DHW: 64 %

-> primary energy factor for DHW: 0.36/0.8*1.24 = 0.56

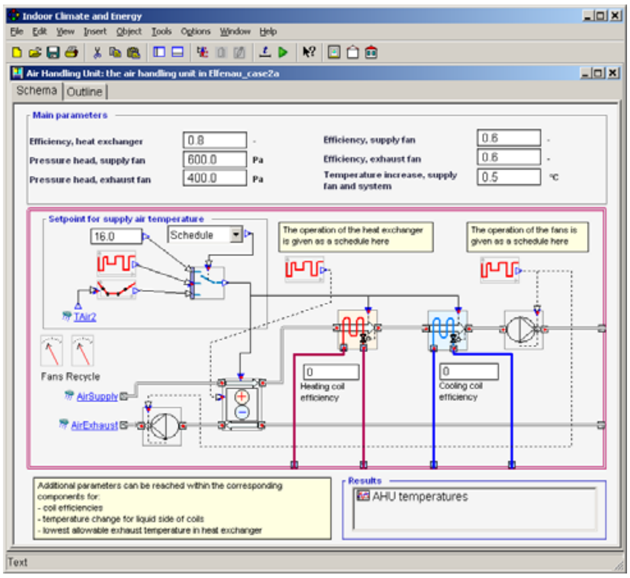
2.2. Heating system



No night setback

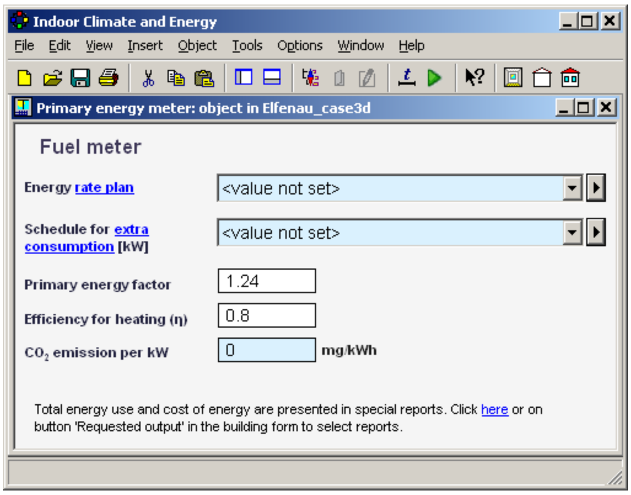
To set the max power of the radiators, an initial simulation was done for the winter design day (-5.95 ... -10.4 °C) with 10 kW max power for each radiator.

2.3. Ventilation system



Supply and exhaust air rate is 0.3 L/(s·m^2). This corresponds to 0.47 h^{-1} air exchange rate or to 35 m^3/(h·Pers)

2.4. Primary energy factors



Heating: 1/0.8*1.24 = 1.55

DHW: 1/0.8*1.24*0.36 = 0.56

Electricity: 0 for the part generated by CHP, 2.97 for the purchased part

3. Results

3.1. Case 3.a (Insulation 20 cm, Glazing U = 0.5)

Flat	Max power design day simulation [kW] case 3.a	Set max power case 3.a [kW]
Basement heated	1.0	2 x 1.0
Groundfloor SE	1.3	3 x 0.9
Groundfloor NW	1.1	3 x 0.7
1st floor SE	1.3	3 x 0.9
1st floor NW	1.0	3 x 0.7
2nd floor SE	1.4	3 x 0.9
2nd floor NW	1.1	3 x 0.7
Attic SE	1.7	2 x 1.7
Attic NW	1.6	2 x 1.6

Results of the design day calculation and the set max power for case 3.a

Case 3.a 783 m^2

	kWh/a	kWh/(m^2·y)
used for heating [1]	2,561	3.3
used for DHW [2]	19,064	24.3
used for both [3]	21,625	27.6
used electricity for fans (and pumps) [4]	2,920	3.7
used electricity for equipment and lighting [5]	23,207	29.6
free electricity from CHP [6] (1/3 * ([1] + 0.36 * [2])	3,141	4.0
primary energy for fans (and pumps) [7] (1 - [6]/([4]+[5])) * 2.97 * [4]	7,588	9.7
primary energy for heating [8] ([1] / 0.8 * 1.24)	3,970	5.1
primary energy for DHW [9] (0.36 * [2] / 0.8 * 1.24)	10,638	13.6
primary energy for heating, DHW and fans [10] ([7] + [8] + [9])	22,196	28.3
primary energy for equipment and lighting [11] ((1 - [6]/([4]+[5])) *2.97* [5]	60,309	77.0
total primary energy use [12] ([10] + [11])	82,505	105.4

Annual energy demand

3.2. Case 3.b (Insulation 15 cm, Glazing U = 0.6)

Flat	Max power design day simulation [kW] case 3.b	Set max power case 3.b [kW]
Basement heated	1.1	2 x 1.1
Groundfloor SE	1.4	3 x 0.9
Groundfloor NW	1.2	3 x 0.8
1st floor SE	1.4	3 x 0.9
1st floor NW	1.1	3 x 0.7
2nd floor SE	1.5	3 x 1.0
2nd floor NW	1.1	3 x 0.7
Attic SE	1.9	2 x 1.9
Attic NW	1.7	2 x 1.7

Results of the design day calculation and the set max power for case 3.b

Case 3.b 783 m^2

	kWh/a	kWh/(m^2·y)
used for heating [1]	3.899	5.0
used for DHW [2]	19.064	24.3
used for both [3]	22.963	29.3
used electricity for fans (and pumps) [4]	2.924	3.7
used electricity for equipment and lighting [5]	23.207	29.6
free electricity from CHP [6] (1/3 * ([1] + 0.36 * [2])	3.587	4.6
primary energy for fans (and pumps) [7] (1 - [6]/([4]+[5])) * 2.97 * [4]	7.492	9.6
primary energy for heating [8] ([1] / 0.8 * 1.24)	6.043	7.7
primary energy for DHW [9] (0.36 * [2] / 0.8 * 1.24)	10.638	13.6
primary energy for heating, DHW and fans [10] ([7] + [8] + [9])	24.173	30.9
primary energy for equipment and lighting [11] ((1 - [6]/([4]+[5])) *2.97* [5]	59.463	75.9
total primary energy use [12] ([10] + [11])	83.636	106.8

Annual energy demand

3.3. Case 3.c (Insulation 10 cm, Glazing U = 0.7)

Flat	Max power design day simulation [kW] case 3.c	Set max power case 3.c [kW]
Basement heated	1.2	2 x 1.2
Groundfloor SE	1.6	3 x 1.1
Groundfloor NW	1.3	3 x 0.9
1st floor SE	1.5	3 x 1.0
1st floor NW	1.2	3 x 0.8
2nd floor SE	1.7	3 x 1.1
2nd floor NW	1.3	3 x 0.9
Attic SE	2.2	2 x 2.2
Attic NW	2.0	2 x 2.0

Results of the design day calculation and the set max power for case 3.c

Case 3.c 783 m²

	kWh/a	kWh/(m²·y)
used for heating [1]	6.467	8.3
used for DHW [2]	19.064	24.3
used for both [3]	25.531	32.6
used electricity for fans (and pumps) [4]	2.932	3.7
used electricity for equipment and lighting [5]	23.207	29.6
free electricity from CHP [6] (1/3 * ([1] + 0.36 * [2])	4.443	5.7
primary energy for fans (and pumps) [7] (1 - [6]/([4]+[5])) * 2.97 * [4]	7.228	9.2
primary energy for heating [8] ([1] / 0.8 * 1.24)	10.024	12.8
primary energy for DHW [9] (0.36 * [2] / 0.8 * 1.24)	10.638	13.6
primary energy for heating, DHW and fans [10] ([7] + [8] + [9])	27.890	35.6
primary energy for equipment and lighting [11] ((1 - [6]/([4]+[5])) *2.97* [5]	57.209	73.1
total primary energy use [12] ([10] + [11])	85.099	108.7

Annual energy demand

3.4. Case 3.d (Insulation 5 cm, Glazing U = 0.8)

Flat	Max power design day simulation [kW] case 3.d	Set max power case 3.d [kW]
Basement heated	1.5	2 x 1.5
Groundfloor SE	1.9	3 x 1.3
Groundfloor NW	1.5	3 x 1.0
1st floor SE	1.8	3 x 1.2
1st floor NW	1.4	3 x 0.9
2nd floor SE	2.1	3 x 1.4
2nd floor NW	1.5	3 x 1.0
Attic SE	2.8	2 x 2.8
Attic NW	2.6	2 x 2.6

Results of the design day calculation and the set max power for case 3.d

Case 3.d 783 m^2

	kWh/a	kWh/(m^2·y)
used for heating [1]	12.570	16.1
used for DHW [2]	19.064	24.3
used for both [3]	31.634	40.4
used electricity for fans (and pumps) [4]	2.920	3.7
used electricity for equipment and lighting [5]	23.207	29.6
free electricity from CHP [6] (1/3 * ([1] + 0.36 * [2])	6.478	8.3
primary energy for fans (and pumps) [7] (1 - [6]/([4]+[5])) * 2.97 * [4]	6.522	8.3
primary energy for heating [8] ([1] / 0.8 * 1.24)	19.484	24.9
primary energy for DHW [9] (0.36 * [2] / 0.8 * 1.24)	10.638	13.6
primary energy for heating, DHW and fans [10] ([7] + [8] + [9])	36.644	46.8
primary energy for equipment and lighting [11] ((1 - [6]/([4]+[5])) * 2.97* [5]	51.835	66.2
total primary energy use [12] ([10] + [11])	88.479	113.0

Annual energy demand

3.5. Case 3.e (No additional insulation for existing constructions, 5 cm for new constructions, Glazing U = 0.8)

Flat	Max power design day simulation [kW] case 3.e	Set max power case 3.e [kW]
Basement heated	2.5	2 x 2.5
Groundfloor SE	2.9	3 x 1.9
Groundfloor NW	2.0	3 x 1.3
1st floor SE	2.7	3 x 1.8
1st floor NW	1.8	3 x 1.2
2nd floor SE	3.0	3 x 2.0
2nd floor NW	1.9	3 x 1.3
Attic SE	3.5	2 x 3.5
Attic NW	2.9	2 x 2.9

Results of the design day calculation and the set max power for case 3.e

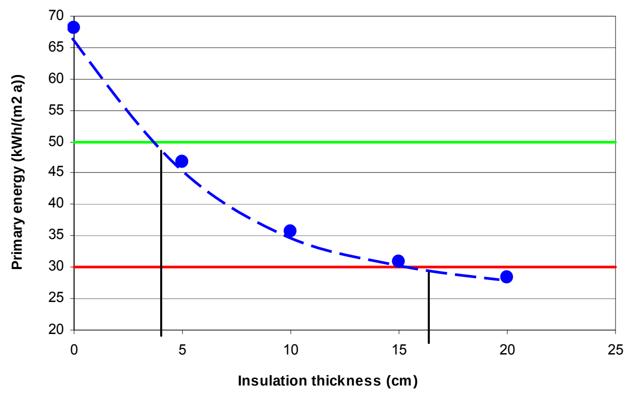
Case 3.e 783 m^2

	kWh/a	kWh/(m^2·y)
used for heating [1]	25.204	32.2
used for DHW [2]	19.064	24.3
used for both [3]	44.268	56.5
used electricity for fans (and pumps) [4]	2.143	2.7
used electricity for equipment and lighting [5]	23.207	29.6
free electricity from CHP [6] (1/3 * ([1] + 0.36 * [2])	10.689	13.7
primary energy for fans (and pumps) [7] (1 - [6]/([4]+[5])) * 2.97 * [4]	3.681	4.7
primary energy for heating [8] ([1] / 0.8 * 1.24)	39.066	49.9
primary energy for DHW [9] (0.36 * [2] / 0.8 * 1.24)	10.638	13.6
primary energy for heating, DHW and fans [10] ([7] + [8] + [9])	53.385	68.2
primary energy for equipment and lighting [11] ((1 - [6]/([4]+[5])) * 2.97* [5]	39.862	50.9
total primary energy use [12] ([10] + [11])	93.247	119.1

Annual energy demand

3.6. Result overview

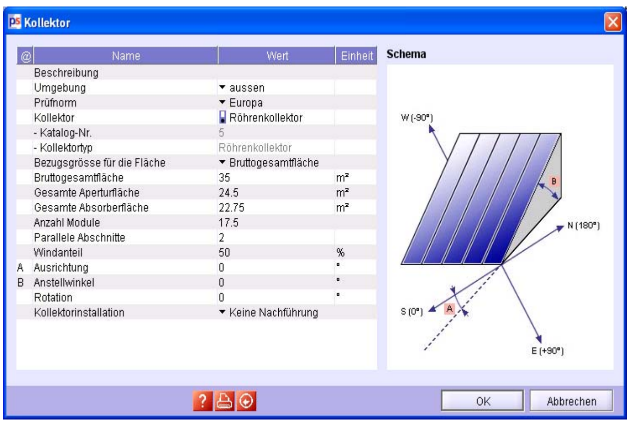
Case	U Glazing W/(m²·K)	Insulation cm	Primary Energy kWh/(m²·y)
		25	
3.a	0.5	20	28.3
3.b	0.6	15	30.9
3.c	0.7	10	35.6
3.d	0.8	5	46.8
3.e	0.8	0	68.2

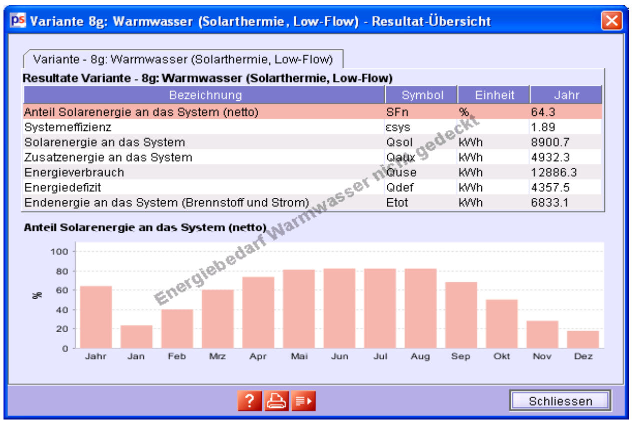


	30 kWh/(m²·y)		50 kWh/(m²·y)	
Construction	Insulation Thickness, cm	U-value W/(m²·K)	Insulation Thickness, cm	U-value W/(m²·K)
Exterior walls	17	0.18	4	0.51
Basement interior walls to non-heated zone	5	0.54	5	0.54
Balcony floor	17	0.20	4	0.66
Interior roof contact with attic non-heated zone	0	1.64	0	1.64
Window frame	--	1.2	--	1.2
Glazing	--	0.8	--	0.6

Glazing g value: 0.5

Solar collectors:





Appendix I
Step 3 Retrofit Case
Calculation Report for Portuguese Location Guimarães

Pedro Silva and Manuela Almeida, University of Minho

1. New Building Area

In order to obtain the new building area it was necessary to add the contribution of the balcony modules and the basement apartments:

Gross heated area: 565 + 79.57 (basement) + 3*8.4*2 (floor 1 to 3 balconies) + 8.78*2 (attic balcony) = 712.53m^2 => BSG indications = **782.5 m^2**

Net heated area: 452 + 65.93 (basement) + 3*[6.94 + 6.79] (floor 1 to 3 balconies) + [7.37 + 7.25] (attic balcony) = 573.74 m^2=> BSG indications = **635 m^2**

2. Heating System

The heating system applied for this case study was similar to the one proposed to the Swiss, i.e. radiator for distribution and emission generated by a central system of an oil fired CHP.

System efficiency (generation and distribution): 90%;

Primary energy factor: 1.24

3. Domestic Hot Water

The DHW needs and energy consumption for the Case Study 3 were obtained applying the official Portuguese tool – SOLTERM – for DHW needs and solar contribution from solar collectors calculation. The results obtained with this tool should be more accurate as this tool was developed specifically for Portugal.

3.1. Type of collector:

Compound Parabolic Concentrating collector (CPC)

Figure I.1 Solar collector

3.2. Backup system

Condensing natural gas water heater with 100 mm insulation on pipes;

- System efficiency (generation and distribution): 90%
- Primary energy factor: 1.15

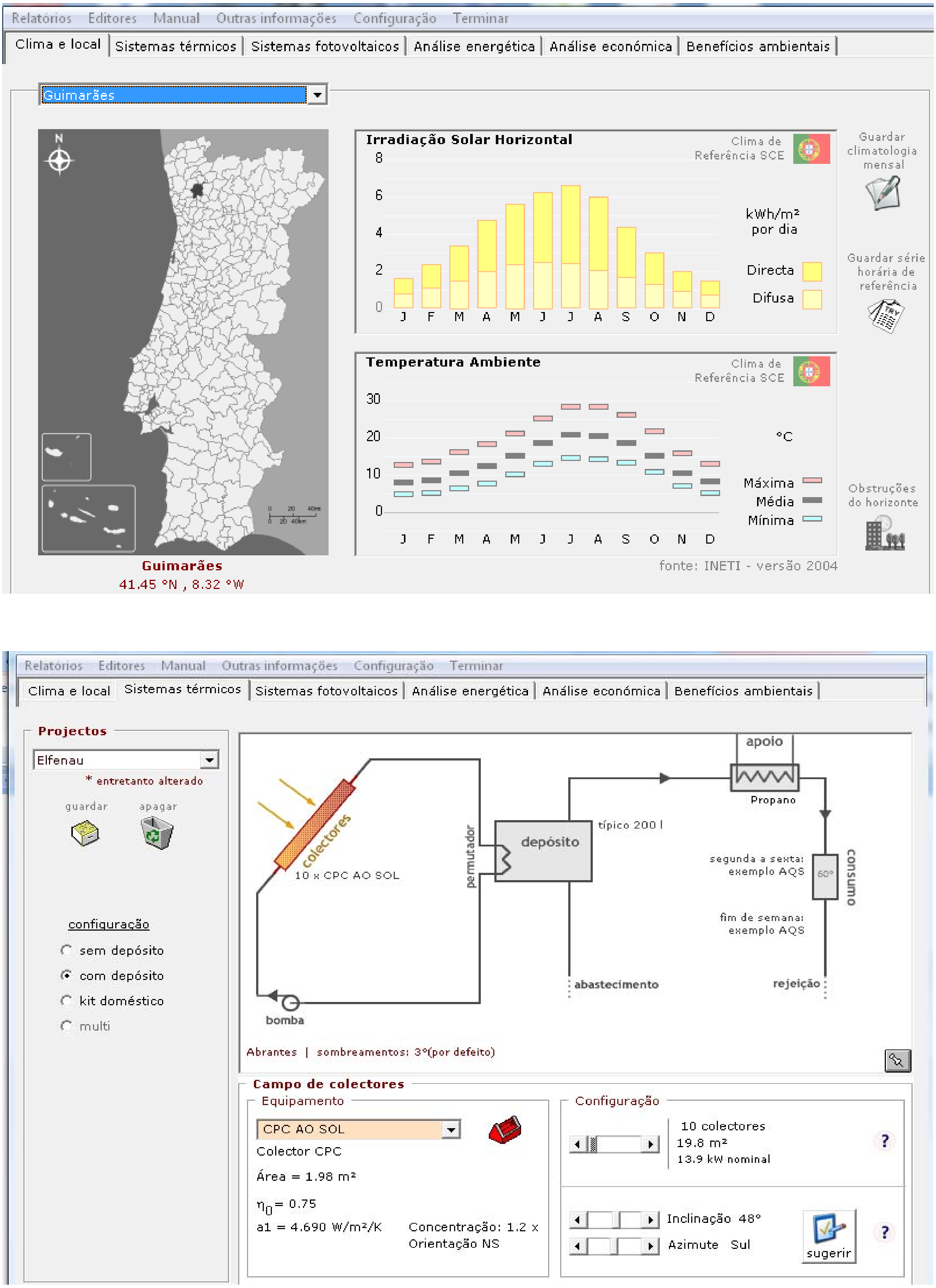


Figure I.2: ***SOLTERM*** *– Climate and chosen System*

3.3. Retrofit to achieve 30 kWh/(m²·y)

Area: 1.98 m² (10 collectors) = 19.8 m²

Total solar contribution for domestic hot water obtained from SOLTERM: 9700 kWh

Table I.1: Allocation of solar gains by apartment:

	Occupants per apartment	**Total nº occupants**	**Solar Gains for DHW** (kWh)
T0 – basement	1	2	404.167
T1 – attic	2	4	808.33
T2 – floor 1, 2 and 3	3	18	1212.15
Total	_	**24**	**9700**

3.4. Retrofit to achieve 50 kWh/(m²·y)

Area: 1.98 m² (8 collectors) = 15.84 m²

Total solar contribution for domestic hot water obtained from SOLTERM: 8000 kWh

Table I.2: Allocation of solar gains by Apartment:

	Occupants per apartment	**Total nº occupants**	**Solar Gains for DHW** (kWh)
T0 – basement	1	2	333.33
T1 – attic	2	4	666.67
T2 – floor 1, 2 and 3	3	18	1000
Total	_	**24**	**8000**

4. Glazings

4.1. Retrofit to achieve 30 kWh/(m²·y)

Saint-Gobain Climaplus Solar Control (double glass) U-Value = 1.1 W/(m²·K)

g_s = 0.45

Introduction of exterior venetian blinds g_s = 0.05

4.2. Retrofit to achieve 50 kWh/(m²·y)

Saint-Gobain Clima Solar Control (double glass) U-Value = 2.1 W/(m²·K)

g_s = 0.45

Introduction of exterior venetian blinds g_s = 0.05

5. Building Envelope

5.1. Insulation to achieve 30 kWh/(m²·y)

Exterior Walls: EPS – 15cm

U-Value = 0.23 W/(m²·K)

Interior walls XPS - 4 cm

(Basement interior walls to non-heated zone): U-Value = 0.67 W/(m²·K)

Balcony floor: XPS - 4 cm

U-Value = 0.68 W/(m²·K)

Interior roof	XPS - 4 cm
(in contact with attic non-heated zone):	U-Value = 0.68 W/(m²·K)

5.2. Insulation to achieve 50 kWh / (m^2·y)

Exterior walls:	EPS – 7 cm
	U-Value = 0.44 W/(m²·K)

6. Heating Needs Calculation

The Case Study 3 was simulated using the DesignBuilder simulation tool to produce the model and the EnergyPlus simulation tool to calculate the energy needs. Following this methodology there were calculated the useful and delivered energy needs.

As required, all the necessary inputs were the ones given to us in the Specifications Document and simulated in Guimarães, a Potuguese city located in the north of Portugal, 50 km away from the sea (GPS coordenates - latitude: 41.4418°; longitude: - 8.29563), thus a climatic file was also constructed: Guimaraes04_UM_Dez03_3DOE2.epw.

However during the simulations there were encountered some ***modelling difficulties***:

- The ventilation system modelling was very complex and several problems were found (will be discussed afterwards);
- It was not possible to edit the model created during Case Study 1 and 2, due to DesignBuilder limitations, in order to introduce the proposed modifications, thus a new model had to be created;
- Due to lack of input data definition, the heating system was not modelled in EnergyPlus. Instead it was used the "Purchased Air" option in order to obtain the building energy needs, and after the necessary effiencies where applied in the excel worksheet.

6.1. Ventilation system

Several problems occurred when trying to simulate the Heating Recovery Ventilation unit in the "Elfenau" building with EnergyPlus:

- Lack of input data;
- No defined schedules for fans or HRV unit;
- EnergyPlus results when including the heat recovery ventilation system simulation presented, systematically, high values of heating needs, which were related to an improperly working system model;
- Wide range of results from the simulation;

Thus, the ventilation system was calculated using the Portuguese Thermal Regulation methodology, considering 1 ACH in every heated zone, simulating a balanced ventilation system that can guarantee no infiltrations =>

$(\dot{V}_{ins} - \dot{V}_{ext})/V > 0.5$

It was considered that the electric consumption of the ventilation system would be distributed by apartment and would count for 45W. Then, the electric consumption of each Ventilator of each apartment would be:

P = Pv*24h*0.03*M

With:

Pv – power – 45 W;

M – Heating or cooling season months.

Then:

$P_{Heating\ Season}$ = 45*24*0.03*7 = 226.8 kWh

$P_{Cooling\ Season}$ = 45*24*0.03*4 = 129.6 kWh

6.2. Model Rendering

To provide a more graphical demonstration of the "Lucerne" building model applied in the simulation, there are presented several print screens of the DesignBuilder model.

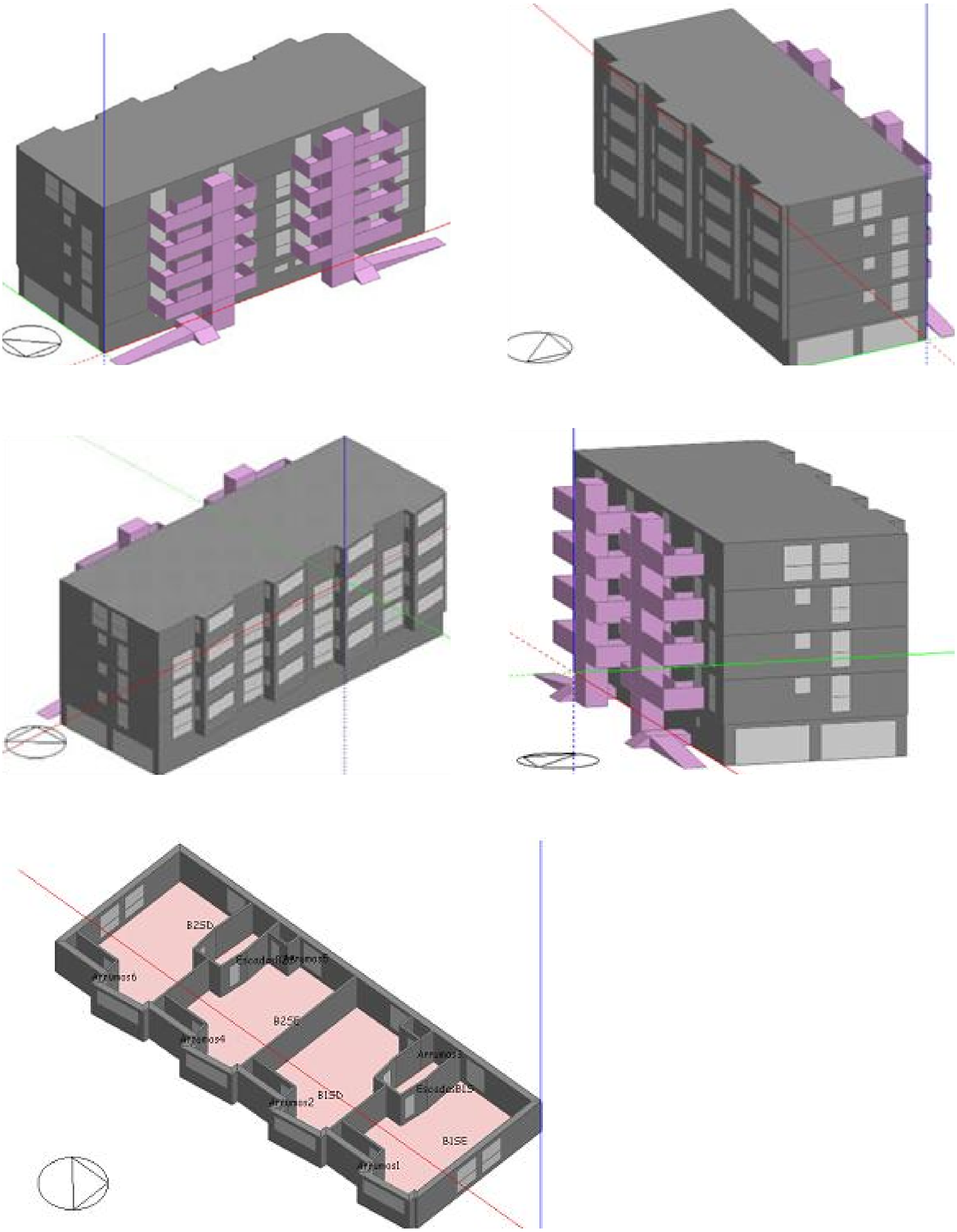


Figure I.3 Graphical representation of the building geometry input

7. Results Case Study 3 - 30 kWh/(m^2·y)

Building Useful Heating Energy Demand (including ventilators consumption):

- 9.5 kWh/(m^2·y)

Building Useful DHW Energy Demand:

- 16.8 kWh/(m^2·y)

Building Useful Total Energy Demand = 26.3 kWh/(m^2·y)

Building Delivered Heating Energy Demand:

- 13.0 kWh/(m^2·y)

Building Delivered DHW Energy Demand:

- 21.5 kWh/(m^2·y)

Building Delivered Total Energy Demand = 34.5 kWh/(m^2·y)

8. Results Case Study 3 - 50 kWh/(m^2·y)

Building Useful Heating Energy Demand:

- 15.6 kWh/(m^2·y)

Building Useful DHW Energy Demand:

- 20.5 kWh/(m^2·y)

Building Useful Total Energy Demand = 36.1 kWh/(m^2·y)

Building Heating Energy Demand:

- 21.5 kWh/(m^2·y)

Building Delivered DHW Energy Demand:

- 26.2 kWh/(m^2·y)

Building Delivered Total Energy Demand = 47.7 kWh/(m^2·y)

9. Results from Simplified RCCTE Calculations

9.1. Results Case Study 3 - 30 kWh/(m²·y)

Table I.7 Energy needs from RCCTE calculations

Auto-nomous fraction N.º	**Nic**	**Ni**	**Nvc**	**Nv**	**Nac**	**Na**
	kWh/(m²·y)					
	Specific winter heating needs	Maximum winter heating needs	Specific summer cooling needs	Maximum summer cooling needs	Specific hot water needs	Maximum hot water needs
B1P1_D	13.09	74.91	12.11	18.00	25.47	42.69
B1P1_E	6.03	74.42	11.37	18.00	25.90	43.41
B1P2_D	3.91	74.42	11.97	18.00	25.47	42.69
B1P2_E	4.76	74.42	11.53	18.00	25.90	43.41
B1P3_D	3.58	74.42	12.44	18.00	25.47	42.69
B1P3_E	4.41	74.42	11.29	18.00	25.90	43.41
B1S_F	16.54	84.82	11.72	18.00	17.88	29.98
B1S_E	14.85	95.31	13.66	18.00	17.74	29.74
B1B_F	7.94	74.42	16.89	18.00	19.72	33.05
B1B_T	8.42	74.42	16.69	18.00	19.51	32.71

* the specific energy needs do not enclose the system efficiency, except for the DHW needs;

** the DHW needs already include the solar panels contributions;

Building Useful Heating Energy Demand:

- 6.7 kWh/(m²·y)

Building Useful DHW Energy Demand:

- 18.9 kWh/(m²·y)

Building Useful Cooling Energy Demand:

- 10.1 kWh/(m²·y)

Building Useful Total Energy Demand = 25.7 kWh/(m²·y)

Building Delivered Heating Energy Demand:

- 10.4 kWh/(m²·y)

Building Delivered DHW Energy Demand:

- 21.8 kWh/(m²·y)

Building Delivered Total Energy Demand = 32.2 kWh/(m²·y)

9.2. Results Case Study 3 - 50 kWh/(m²·y)

Table I.8 Energy needs from RCCTE calculations

Auto-nomous fraction N.º	**Nic**	**Ni**	**Nvc**	**Nv**	**Nac**	**Na**
	kWh/(m²·y)					
	Specific winter heating needs	Maximum winter heating needs	Specific summer cooling needs	Maximum summer cooling needs	Specific hot water needs	Maximum hot water needs
B1P1_D	23.59	74.91	8.74	18.00	28.39	42.69
B1P1_E	16.22	74.42	7.75	18.00	28.95	43.53
B1P2_D	8.99	74.42	8.59	18.00	28.39	42.69
B1P2_E	12.80	74.42	7.86	18.00	28.95	43.53
B1P3_D	6.31	74.42	9.09	18.00	28.39	42.69
B1P3_E	10.91	74.42	7.78	18.00	28.95	43.53
B1S_F	38.22	84.82	10.49	18.00	19.94	29.98
B1S_E	37.52	95.65	11.69	18.00	19.78	29.74
B1B_F	14.16	74.42	11.83	18.00	21.98	33.05
B1B_T	32.68	83.29	13.46	18.00	30.40	45.72

* the specific energy needs do not enclose the system efficiency, except for the DHW needs;

** the DHW needs already include the solar panels contributions;

Building Useful Heating Energy Demand:

- 15.5 kWh/(m²·y)

Building Useful DHW Energy Demand:

- 21.1 kWh/(m²·y)

Building Useful Cooling Energy Demand:

- 7.4 kWh/(m²·y)

Building Useful Total Energy Demand = 36.6 kWh/(m²·y)

Building Delivered Heating Energy Demand:

- 24.0 kWh/(m²·y)

Building Delivered DHW Energy Demand:

- 24.3 kWh/(m²·y)

Building Delivered Total Energy Demand = 48.3 kWh/(m²·y)

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EMPA
Materials Science & Technology

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