CHALMERS

Office building performance

Software based energy calculation of office buildings and comparison with measured energy data

Master of Science Thesis in the Master's Program ERASMUS

MARIE DRUHEN

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CHALMERS UNIVERSITY OF TECHNOLOGY

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Thesis 2013:28

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Cover:
Office building

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ABSTRACT

The usage of energy simulation tools is widespread in the construction field. Indeed, it is useful to predict the energy consumption of a new building, or try to find the cost effective ways to reduce the energy consumption of an existing building. The basic building's parameters are easy to enter in software tools, but the behaviour of the users or the maintenance quality of the systems is not easy to predict. Thus it is interesting to see how the calculated energy consumption matches with the real energy consumption of a building. Integrated in a two years lasting project in Switzerland with the aim to evaluate the building´s design and energy characteristics influence on well-being, comfort and performance of employees in office buildings, this project work aims to compare the energy demand and the actual energy consumption of an representative office building sample.

This is done by using all the data collected during the project, such as building's envelope characteristics, heating and cooling systems or user behaviour. These input data have been fed in the software LESOSAI that is specialized on thermal balance calculations of buildings.

The main conclusion of the study is that there is a difference between measured and calculated value. Among the 6 simulations realized, what can be said globally is that the calculated heating consumption is higher than the real one, and vice versa for electricity. But the gap differs from one building to another. That can be explained partly by the quantity and accuracy of the given data that is not the same for every building.

Moreover, the sensitivity of the results reveals that some small assumed parameters can create variation in the final consumption.

However, the results are rather reasonable. The relation between electricity and heating consumption is logical, if the electricity consumption is higher than expected; the heating consumption will be lower thanks to the heat released through the electric devices.

Key words: Software, energy calculation, office building, user behaviour

Contents

1 Introduction

1.1 Background

In Switzerland, the management of the Swiss building stock is responsible for 45% of the total energy consumption. As the energy is becoming precious and expensive, the energy improvements in building, such as the refurbishment of the envelope to reach a better insulation, or the replacement of the heating system to gain in efficiency, have been studied and experimented and it is known that it enable large savings. When thinking about the way to better a building, the technical part is always easy to estimate, in the way that everything can be calculated. What is hard to expect is the behaviour of the users because there is no calculation available to predict it.

Nevertheless, if we focus on office building, the salaries of office workers are the highest cost for the company, before building energy and maintenance costs. That means that the comfort and productivity level of employees should be important concerns for the companies. In addition, an office building is expected to host a large number of workspace users, that won't behave in the same manner. Therefore, it would be interesting to analyse the interaction between the users and the performance of the building. But up to now there is a lack of empirical parameters related to the user knowledge and point of view about the energy use in their working environment and their well-being.

That's why ZHAW Wädenswil (Zürcher Hochschule für Angewandte Wissenschaften) and ETH Zürich (Eidgenössische Technische Hochschule) have done a 2 years lasting research concerning the impact of the building quality on the well-being and the performance of the users.

Among 25 office buildings in Switzerland, measurements and questionnaires have been performed in order to compare the quality of the building to the health, comfort, performance and behaviour of the users.

1.2 Purpose

The aim of the study is to use the data that have been collected in the project: *"Quality of sustainable office buildings"*, such as description of the building, details concerning facilities, envelope components or systems. The collected data will enables to realise a software based energy calculation that will give the energy demand of the building sample. This energy demand will then be compared with the measured one, also given by the building manager. The possible dissimilarity between the software result and the real consumption can give a hint on the influence of the users on the performance of the buildingAlong with the building's simulation, the impact of each building's parameters will be analysed so as to know which one are essential.

The questions that will be answered in this project are:

Are the simulated values similar to the measured ones?

What are the main drivers for the energy consumption of the buildings assessed?

Is it possible to cluster the buildings/drivers according to the findings achieved?

How are the building ranked in terms of energy efficiency?

1.3 Objectives and method

As the accessible data, obtained thanks to the partners of the project, are not based on the software requirements, it's good to first have a literature study in order to assume the parameters we miss and know the impact of the assumptions on the precision of the result. This is done, inter alia, by using the European project TABULA and LESOSAI's database, and also by performing a simple example simulation and change the parameters one by one to compare the impact on the results.

Then, all the information available thanks to the project process are collected and organized. The principle is to use the CECB (Cantonal Energy Certificate for Buildings) model on each building. It enables to calculate the amount of energy needed with a given use of the building. The modelled buildings receive a grade between A and G ("really energy efficient" to "not efficient").

1.4 Framework conditions

The work is based on the information given by the project managers. The information given, for each building, is variable; sometimes we have the U-value of the envelope element, or just the kind of construction and same discrepancy for the systems and system's regulation. Also, for few buildings only, the consumed energy for heating and electricity during the last years is given.

Due to the short time of my project and the time it takes to have all necessary data, only 5 among 25 buildings have been simulated.

2 Methodology

In the following part the way of getting the results will be presented, which means, how the software has been used, how the given data have been taken into account and where the assumed values come from.

2.1 Module used in LESOSAI

The software used to perform the simulation is LESOSAI. **LESOSAI 7.2** is software for the certification and thermal balance calculation of buildings containing one or more heated or cooled zones. It is designed primarily for building engineers, HVAC engineers and architects. It can use many calculation methods and it has the advantage of being used in many countries as Switzerland, France, Italy, Germany, and United Kingdom. Moreover it offers free licenses for students during a short period, if there is a need for a project work.

As it is not focused on one country, LESOSAI contains a lot of calculation methods based on the different regulation (RT2012, SIA...). The buildings are all located in Switzerland, so we will use the Swiss regulation. The task is to compare all the buildings, the chosen criteria are: the space heating and cooling demand and electricity demand. The best module in order to do that is *SIA 2031 Hourly label.* This method takes into account the envelope, the use of the building and the system for cooling, heating and hot water supplying. The results given are the final and primary energy needs (electric, cooling and heating), the temperature inside the building, the internal gains (solar radiations trough each window). All this parameters can be observed all along the year, with an hourly resolution.

In addition, LESOSAI contains a database with default values for each parameter that can still be used if there is no clue about the state of the system or components.

The following print screen of the software enables to know what kind of results is given.

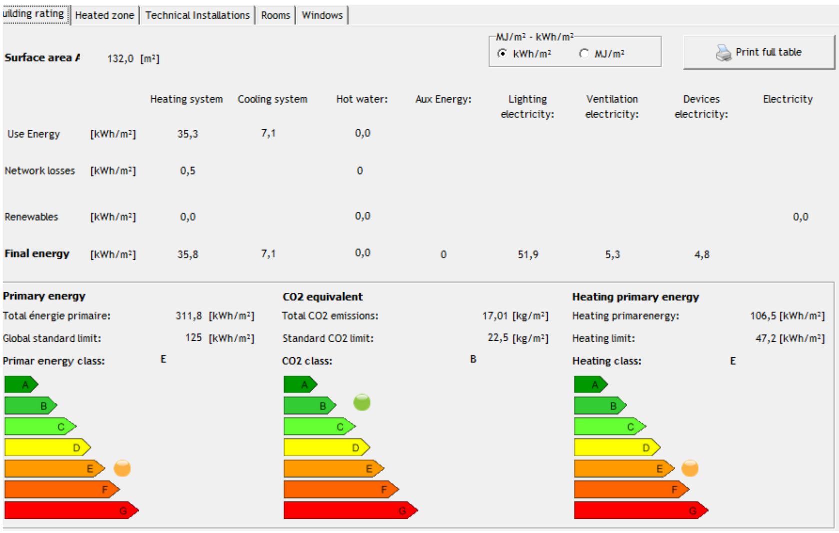

Figure 2.1.a Results obtained with LESOSAI's calculation: energy consumption.

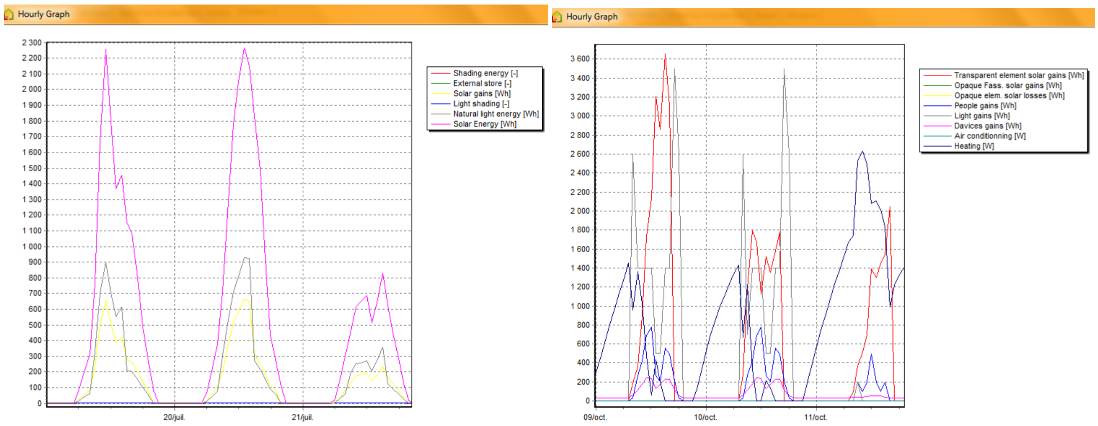

Figure 2.1.b   Results obtained with LESOSAI's calculation: daily energy distribution.

2.1.1 Weather database

The exact location of each building is given and it is entered in LESOSAI. The software uses a weather database called Meteonorm. It contains calculations averaged over a long term of overall radiation, temperature, dew point and wind. For temperature and humidity, monthly averages are based on the period from 1996 to 2005. For global radiation, the main period is from 1981 to 2000. The uncertainty of the interpolation of annual average is 7% for global radiation and 1.4°C for temperature.

The given energy data from the office building have been measured between 2000 and 2009. The Figure 2.2 shows the evolution of the yearly mean temperature over 20 years in Zürich. The conclusion of this observation is that the difference of temperature between the period 1996-2005 and 2000-2009 is not significant enough in Zürich, to alter the result.

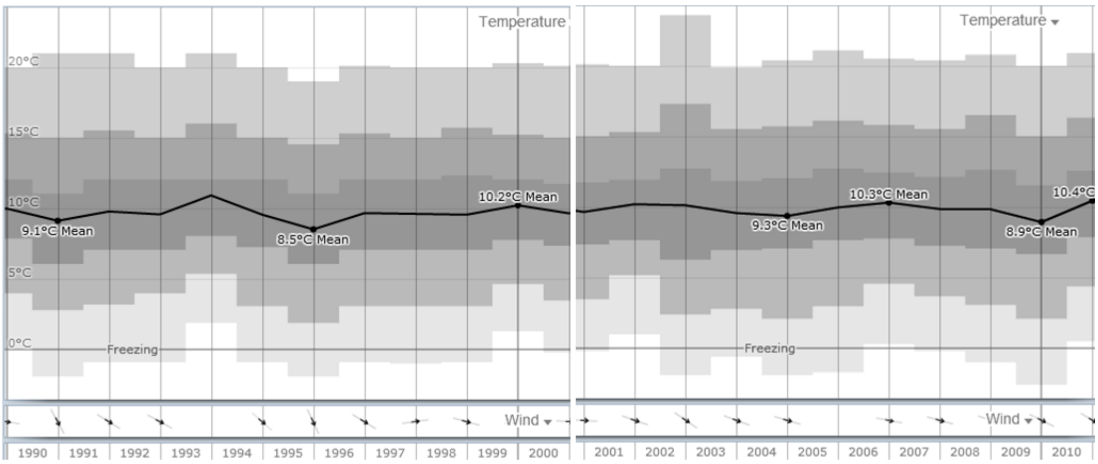

Figure 2.2   Black line=yearly mean temperature evolution between 1990 and 2010; the grey areas show the percentile (10/25/30/60/75/90) (Source: Weather Spark)

2.2 Building description

The chosen buildings for the research project respond to several common criteria so as the measurements are easily done and the results enable a good representation of the building stock. All the buildings are used as office building; they must be as homogenous as possible and must contain at least 100 employees. They are located in Switzerland, mostly in Zürich and Bern area. Often the buildings contain a restaurant for the employees, conference rooms, customer or waiting rooms, technical rooms, personal office and open office. They have been constructed between 1915 and 2007; most of them have been partially renovated and some of the buildings have a Minergie certification which is a registered quality label for new and refurbished low-energy-consumption buildings, supported by the Swiss Confederation, the Swiss Cantons and the Principality of Liechtenstein along with Trade and Industry.

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2.2.1 General characteristics of the building sample

Each company that takes part in the project gives the information that will enable to answer the main question: "How do office buildings impact the comfort and productivity level of workplace users?" Number of this information is useful for my project. Such as blueprint of every storey, with the arrangement of the working space, pictures of the building, from outside and inside, and a questioner filed out by the building manager, where information concerning the company activity, the building envelope characteristics, the workplace facilities and energy data over the last years appears. Attached with the consumption's values, the important modifications performed on the building are stated. The Table 2.1 provides an overview of the given data. Much more information is given, but as they are not all useful for the simulation, they are not shown here.

Table 2.1 Diverse information provided by the questionnaire.

<table>
<tr><td rowspan="3">Use</td><td colspan="3">Year of construction (and refurbishment)</td><td>1994 / deep boiler replaced / chiller changed</td></tr>
<tr><td colspan="3">Workers repartition</td><td>276: Ground floor=23 / 1st floor=106/Basement=0/ 2nd floor=52 / 3rd floor=77 / 4th floor=44 / 5th floor =61</td></tr>
<tr><td colspan="3">Rooms</td><td>Restaurant, server rooms, printing</td></tr>
<tr><td rowspan="2">Envelope</td><td rowspan="2">Walls</td><td>Components</td><td>U-value (W/m²K)</td><td>0.38</td></tr>
<tr><td>Windows</td><td>U-value/ operable ?</td><td>1.9 W/m²K – double glazing / area=70%</td></tr>
</table>

			store (ext/int)	Venetian stores outside / manual override per axle or office / automatized
Systems	**Heating**	**Energy carrier**		Oil and Gas
	Cooling	**Emission type**		Cooling ceiling
Ventilation	**Mechanical or natural ventilation / windows open**			Windows operable / mechanical ventilation / humidification
Measured data	**energy reference area (m²)**			7850
	Volume m3			50240

In this example, the U-value of the wall is given, but most of the time, only the type of construction is given, as "ventilated facade element" or "perforated facade". The room's area distribution is often given and information about light is also provided.

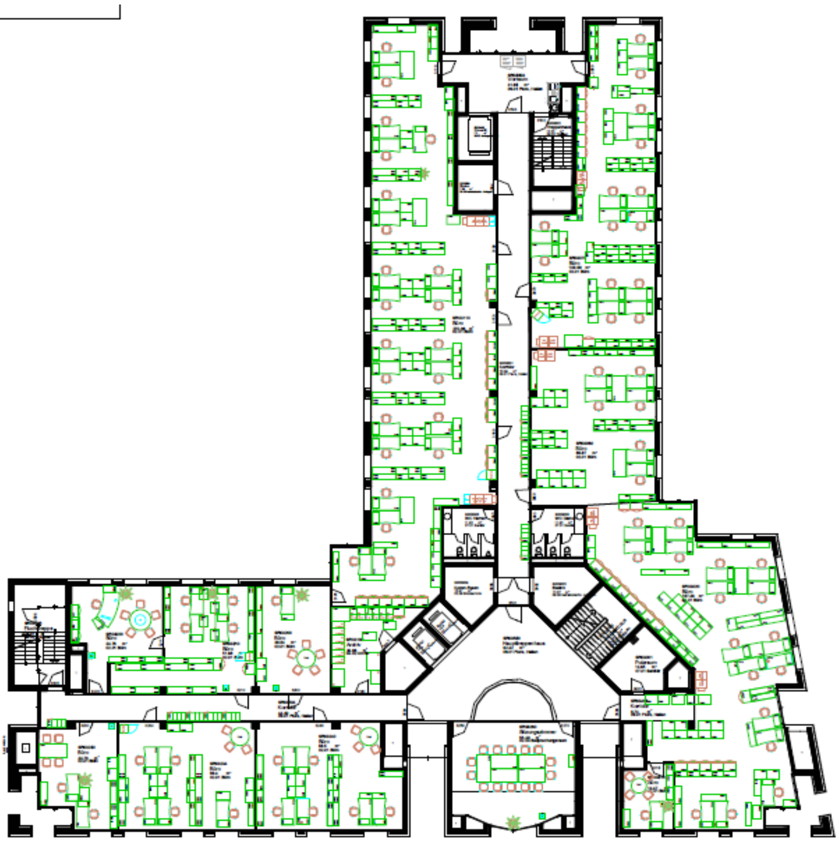

Figure 2.3 Blueprint of one building.

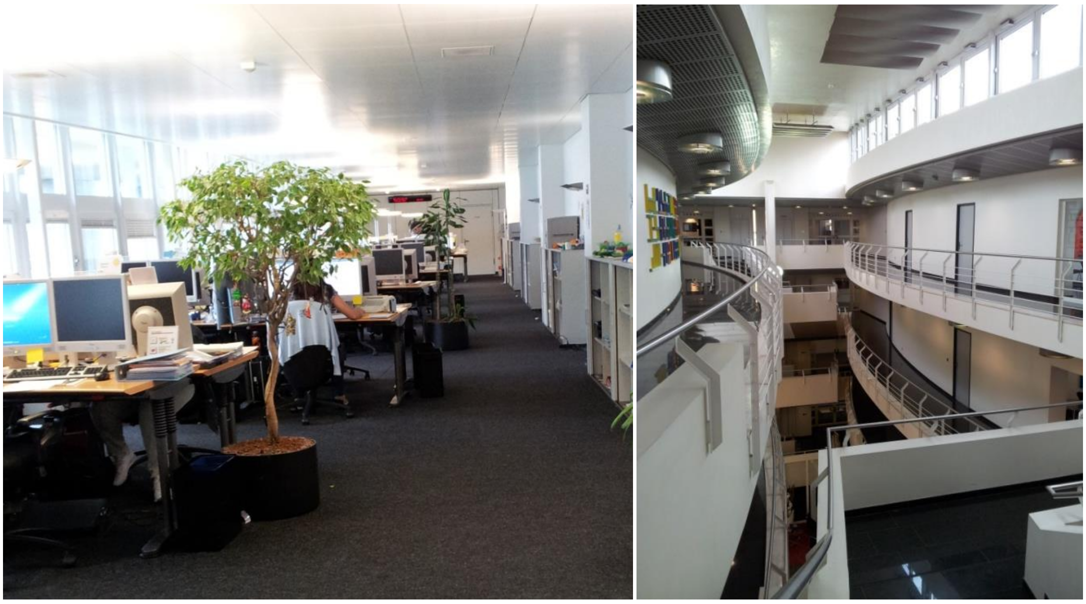

Figure 2.4 Given picture of the workspace.

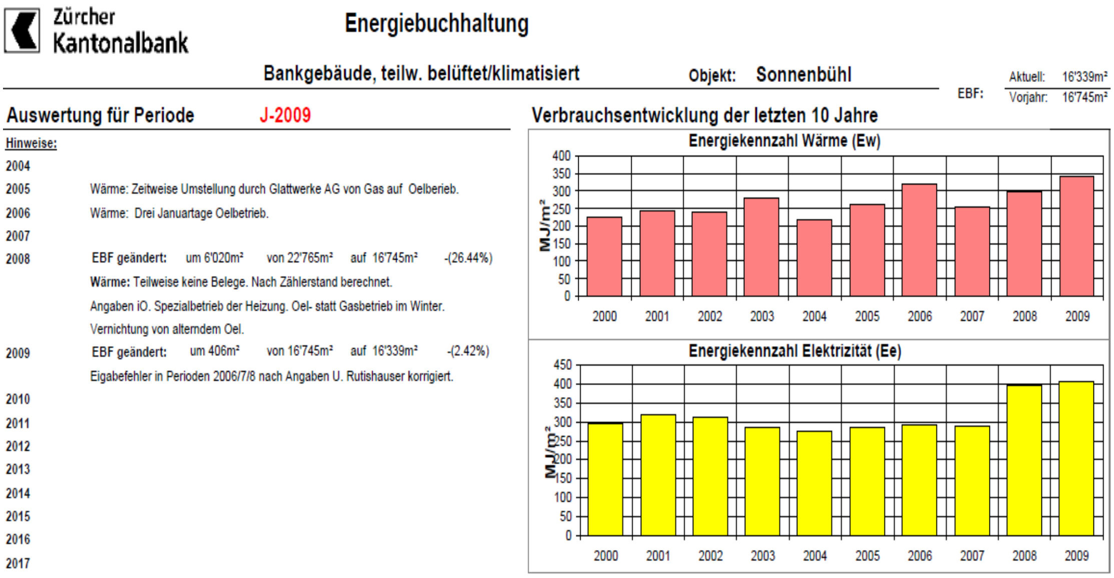

Figure 2.5 Heating and electricity consumption during the last 10 years, for one of the building.

2.2.2 Common parameters

A number of parameters are similar for the different buildings. First they are all used as office building, thus the occupation time is the same for each (detailed in part 2.3). Then, the operative temperature is 21 °C in winter and 26°C in summer excepted if real temperature data are available (for example, 23°C in winter have been measured in one building). All the buildings are lighted with fluorescent light, some are automatically regulated.

The thermal bridges have been neglected in all the buildings, because there is no reasonable assumption, since their impact will vary if the envelope is well insulated or not, and compared to other parameters such as the operability of the windows, the impact is low.

2.3 Input requirements from LESOSAI

In this part, what is needed to be entered in the software to perform the calculation and answer the aforementioned questions will be presented.

For the sample buildings, the heating and electricity consumption observed during the last few years is given, and this consumption correspond to the entire building, including kitchen if there is one, or workspace and seminar room. That is why the simulation performed deals with the entire building.

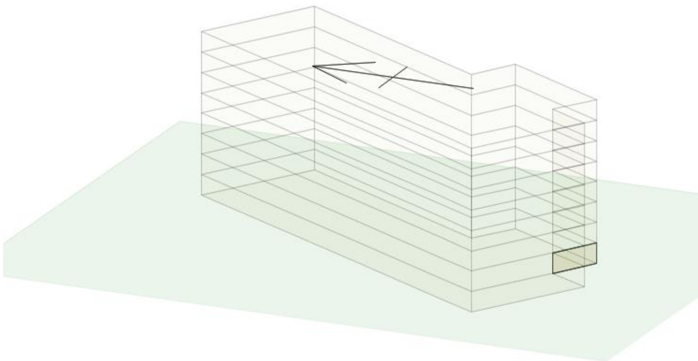

Figure 2.6 3D view of one building, on LESOSAI

The parameters can be sort into few main categories: at first the envelope of the building, by the U-values or description of each construction element, permits to know how much energy is lost through the envelope and how the buildings behave in summer conditions.

Next the systems used for cooling and heating, the energy carrier and the regulation principle, later the ventilation system with the air flow and working time.

In the end, all the parameters that describe the use of the building: the operability by the employees of diverse elements, like windows or light. This announces the internal gains that the systems have to face with, and also enables to know if the attitude of workers leads to saving energy.

The next four Figures show an overview of what is filled in the software.

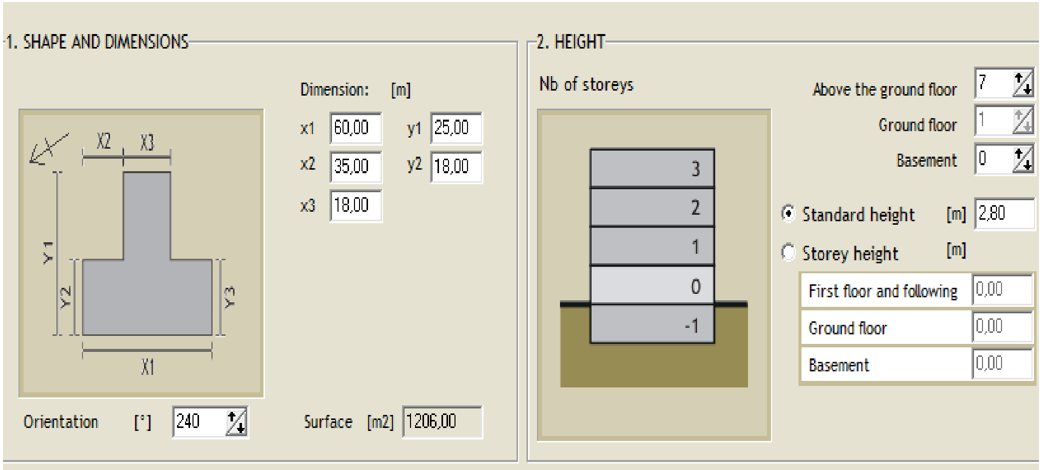

Figure 2.7 Geometry and orientation of the building.

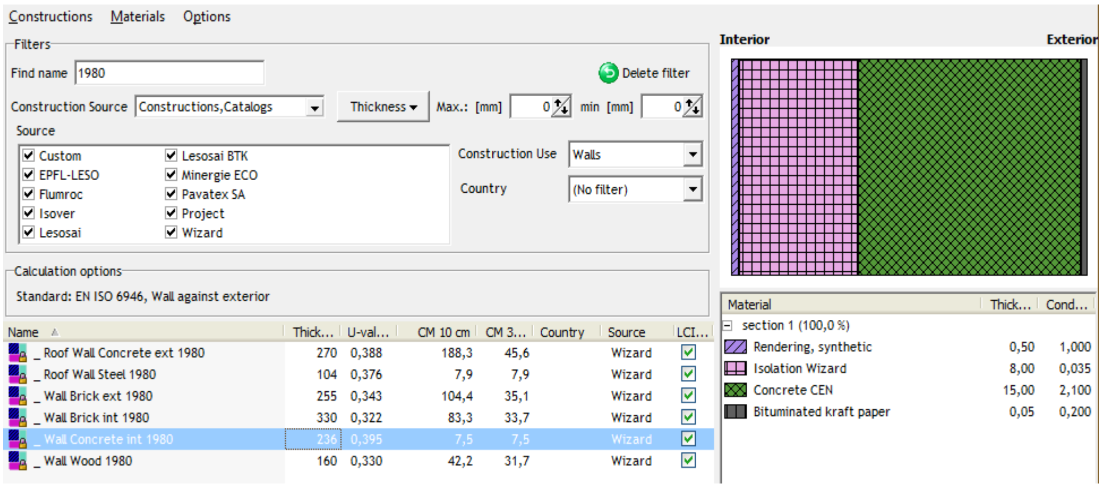

Figure 2.8 Wall components.

If the elements are known the construction can be created in the software layer by layer, otherwise it is possible to just enter the U-value of the construction.

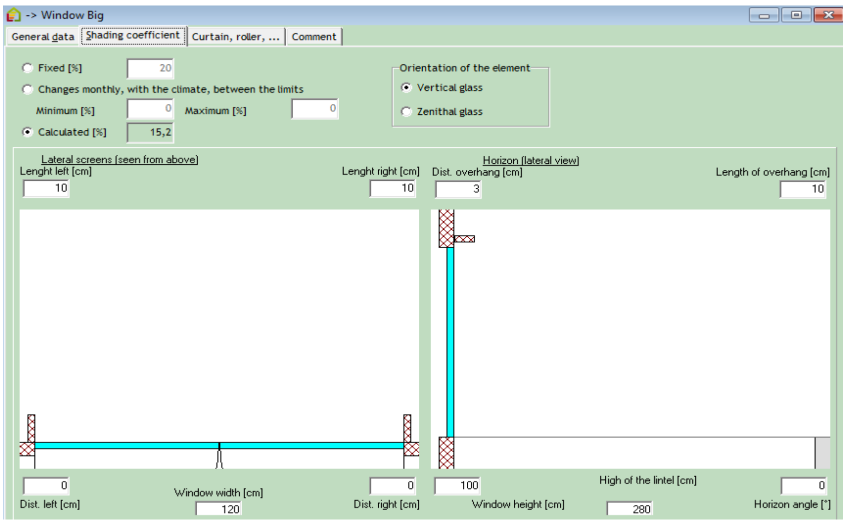

Figure 2.9 Windows size and shading.

In the software there is a database for occupation time in the building. There is an affectation for office, a different one for open office, or meeting room. As the schedule of each building is not known, the one from LESOSAI is used. You can see in the Figure 2.10 the occupation scenario for a usual office. The graphs represent the percentage of occupation, per day, week, month, and year. The number of employees for each building (sometimes in a smaller scale: for each store) is filled out by hand as it is known. With both of these information the number of people, and so the heat they provide, is known.

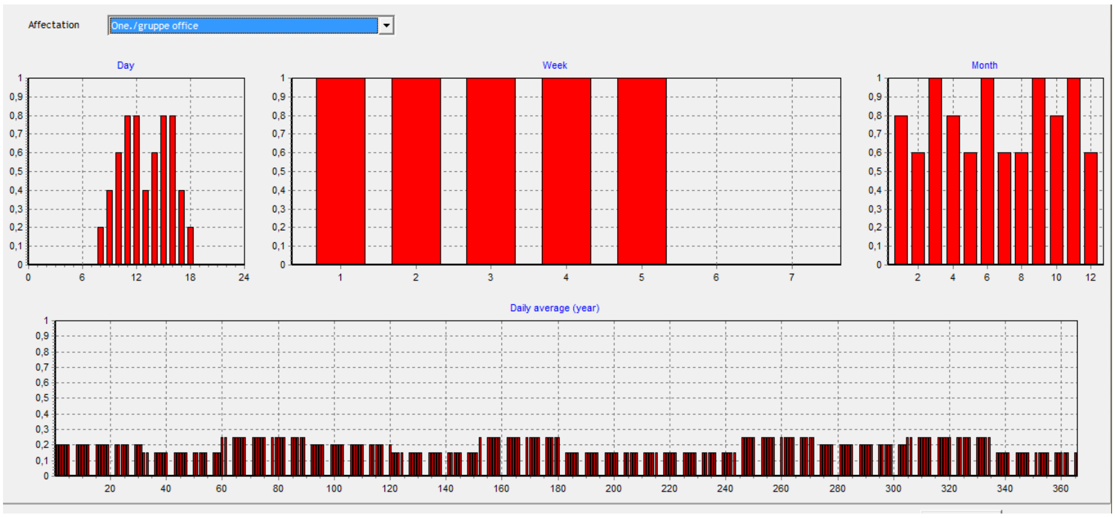

Figure 2.10 Occupation rate for office building, given by LESOSAI.

Table 2.2 All the parameters that has been filled in the software for the 5 simulated buildings.

Parameters				BKW_Bern	ZKB_HardA	ZKB_Ringhof	ZKB_Josefstr	ZKB_Untertor
Use	Year of construction (and refurbishment)			1959 (2003 façade /2008 Heat pump)	1973 (2000 façade)	1994 (boiler/chiller changed)	2004 (Minergie)	1980 (2009 façade)
	Workers			302	303	276	688	320
	Area (EBF) in m²			7 462	10 506	9 750	12 610	5 700
Envelope	Walls	Components	U-value (W/m²K)	0,335	1	0,38	0,15	0,3
		Windows	U-value (W/m²K)	1,1	3,3	1,9	0,8	0,6

			area in %	35	45	70	60/10/30	50
			store (ext/int)	some (external)	Internal	External	External	External
	Roof	Components	U-value (W/m²K)	0,3	0,51	0,51	0,15	0,3747
	Floor	Components	U-value (W/m²K)	0,3845	0,8	0,21	0,161	2,6976
System	Heating system	Energy carrier		District heating	District heating	Gas(97%)/ Oil (3%)	District heating	District heating
		Efficiency in %		90	90	95	95	90
		Insulation		10mm	10mm	20mm	20mm	10mm
	Cooling system	Energy carrier		Electricity	Electricity		District heating	
		Efficiency in %		80	80		95	
Ventilation	Humidification / pre heating…					Humidification	Hum and pre-heat	De-hum / air cond
	Heat exchanger			Yes, with 60% efficiency				
	Air flow (m3/h)			197 195	41 550	192 267	37 970	15 777
	Windows			Windows operable 5° 1h if Text>18 °C Night cooling when Tmax>26°C	not operable	window open during lunch if Text>18°C	Windows are not operable	Windows are not operable

2.4 Assumption for the missing data

A number of parameters are necessary to create the software energy model of the building. When we don’t know a parameter, an assumption should be set, and it has to be as objective as possible, depending on the year of construction and according to other parameters that we know, also with the comparison with other similar building for which we have the data.

The more information we get from the building owners, the more accurate the result will be. However, collecting so many data and details can be tricky, and a number of parameters have to be assumed for each building. In order to keep a coherent result among the buildings, it’s relevant to use good archetypes. I choose to have at least two different sources so as to compare the models and to take the more accurate for each corresponding situation. Here follow the description of the sources and a summary of the useful values.

2.4.1 IEE Project TABULA

One of my sources, the IEE project TABULA, has been executed between June 2009 and May 2012. The specific objective of the project is to elaborate a set of model buildings for each participating country, which can be used as representatives of the national building stock, with a focus on residential buildings. Unfortunately there is no Swiss office building, but the German building stock is assumed to be similar to the Swiss one, so it still gives an idea of the kind of construction, depending on the year when the building has been erected.

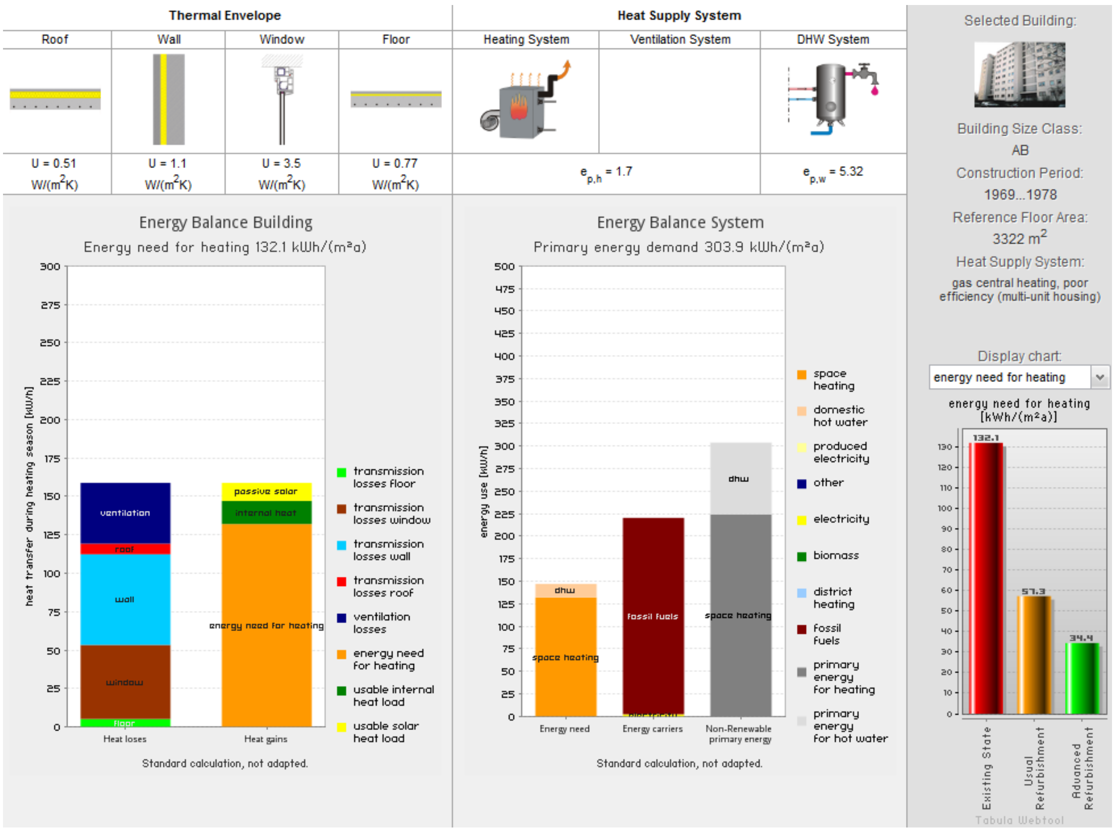

Figure 2.11 Given data by TABLUA project.

The averaged evolution of the U-value for the main element of the building envelope, according to the project TABULA, appears in the Figure 2.11. The U-value of each component after basic or advanced refurbishment is also given.

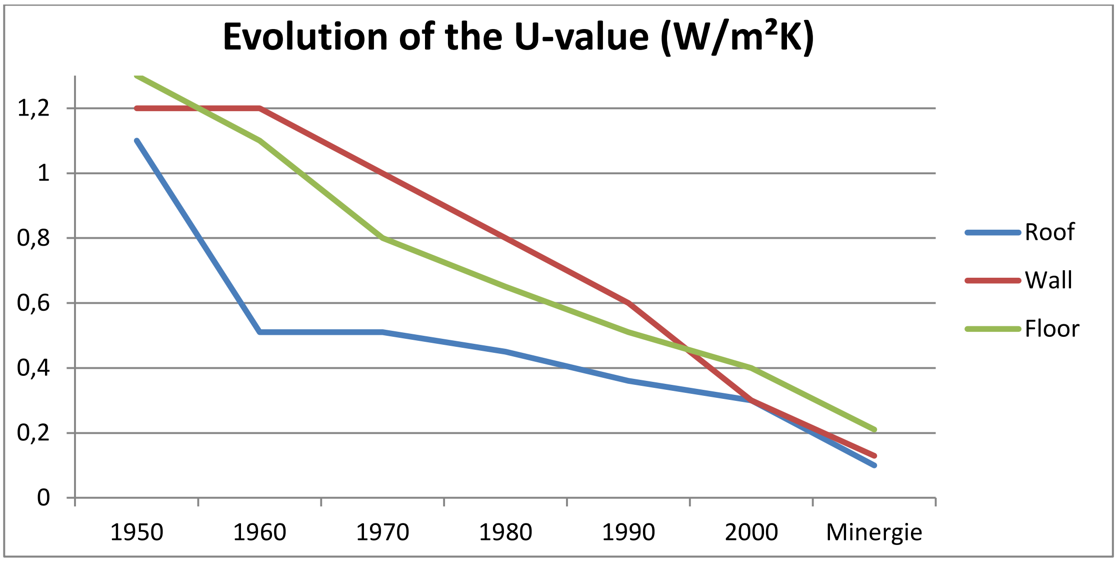

Figure 2.12 Averaged evolution of the U-value obtained from TABULA's research.

As a number of assumptions have been made to come up to these values, they are used only if no other information is available, and it permits to be coherent between the entered values in the software and the year of construction of the buildings.

2.4.2 LESOSAI's database

LESOSAI contains a construction library, in which we can find typical construction, depending on the component of the construction and the year of construction or the thermal class. For instance, for a building made of concrete, in 1980, the U-value of the floor is 0.544 W/(m²K) (330 mm thick) and the one of the roof/wall is 0.388 W/(m²K) (270 mm thick).

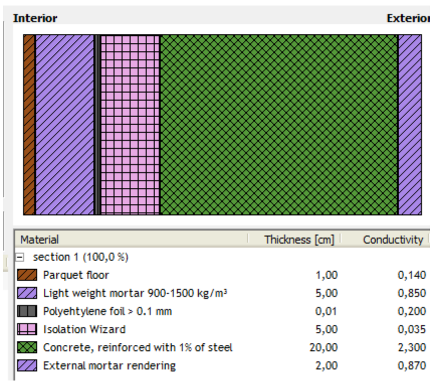

Figure 2.13 Floor made of concrete in 1980, construction detailed by LESOSAI.

2.4.3 Other assumptions

What is mostly missing in the data given by the companies, are the parameters related to the use of the building. Indeed, the number of computer, the specific power supply, the existence of personal lighting, the number of printers and the characteristics of the server room, are not given. Archetypes are chosen for each of the last parameters, they are the same for all buildings. The used data are explained in the Chapter 3, in the section 3.2.2.

3 Results

3.1 Simulation's results

As it has been said before, LESOSAI doesn't deliver only the annual consumption, indeed, after the first simulation, the coherence of the result is examined, and sometimes few parameters are changed in order to have a more plausible consumption. As an example, a quick look at the solar radiation graph enables to know if the windows are well oriented and if the curtains are well set.

The energy balance and the temperature graphs enable to know if the system regulation is right.

The following print screens show the results obtained for the building "ZKB_Hard A".

Figure 3.1 Building energy performance assessment.

This is calculated over a year. The scale show the primary energy, which takes into account all the conversion or transformation process, but the energy data given by the companies is final energy, i.e. the amount of energy they have to pay for.

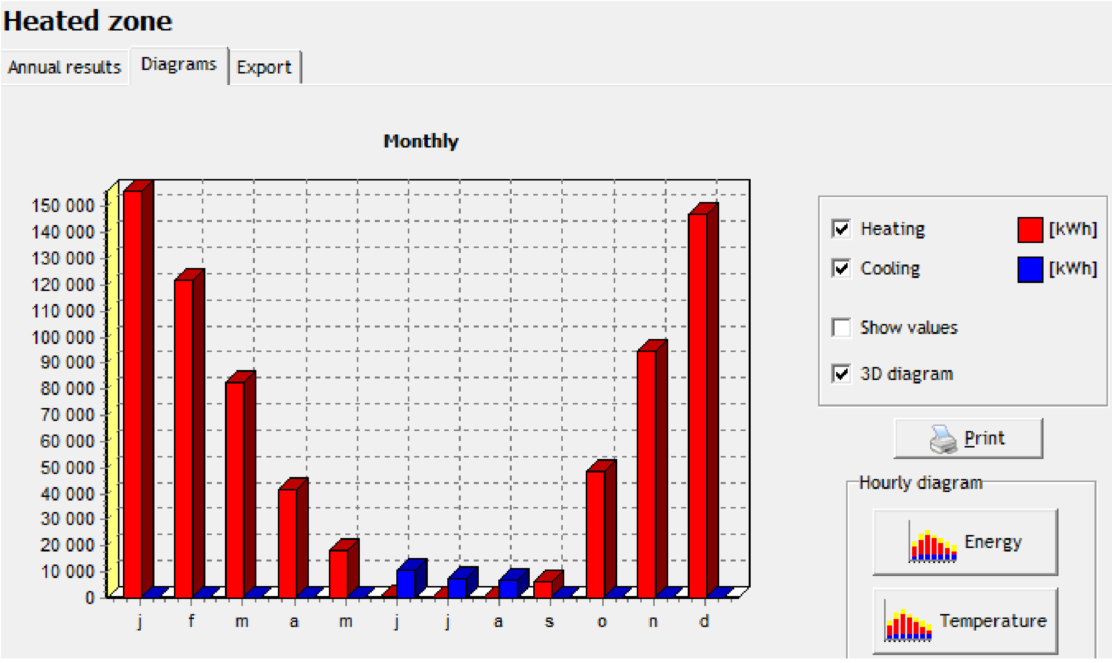

Figure 3.2 Energy heating and cooling needs, given month per month.

The cooling needs are low; in the Figure 3.4 we observe that the curtains are efficient.

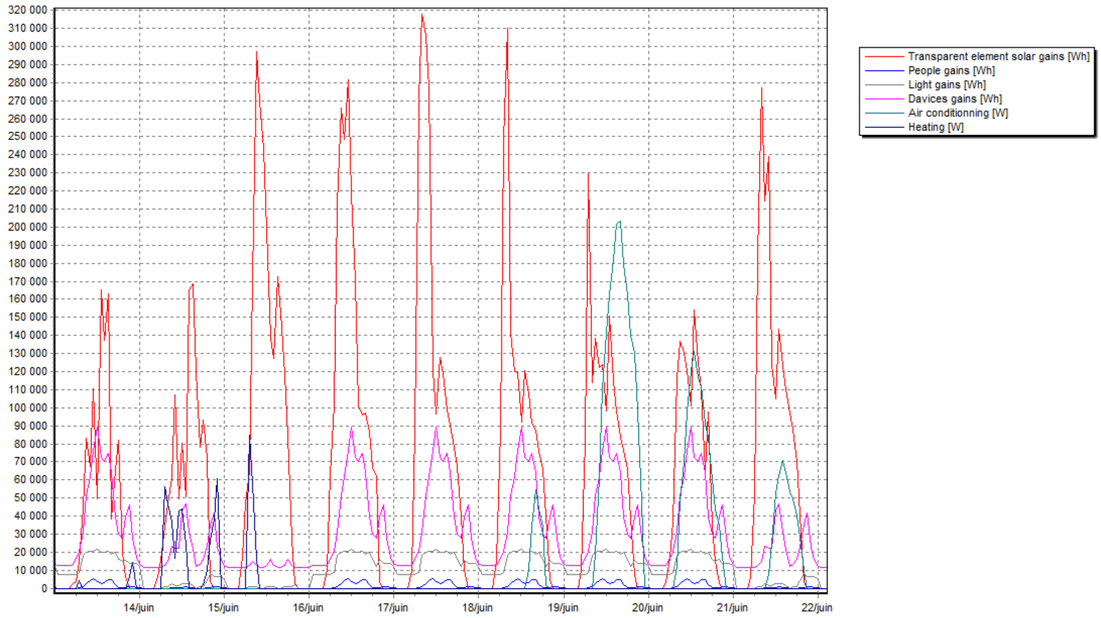

Figure 3.3 Energy balances in the building during one week.

We can see here that the heating system is working during the week end: as there is no people and the devices are off, the need for heating increase, but in the real life, the heating system is shut off for the warm season: in the next simulation of the building, this error will be corrected.

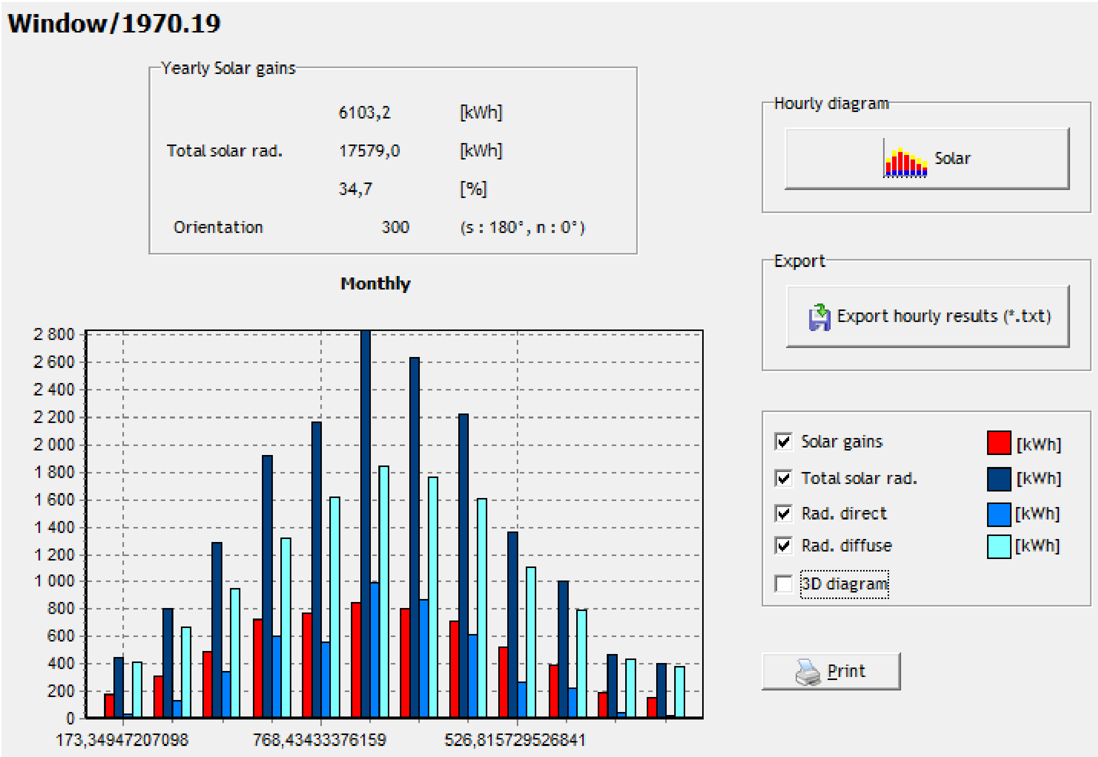

Figure 3.4 Solar radiation and gain through one window facing the South.

We observe in this graph that the effective solar gains (in red) are quite low compared to the sun radiation that reach to the exterior part of the window, this is because of the curtains that are used often and are efficient.

Table 3.1 Main characteristics fed in the software and the result obtained, for 5 buildings.

<table>
<tr><th colspan="4">Parameters</th><th>BKW_Bern</th><th>ZKB_HardA</th><th>ZKB_Ringhof</th><th>ZKB_Josefstr</th><th>ZKB_Untertor</th></tr>
<tr><td rowspan="3">Use</td><td colspan="3">Year of construction (and refurbishment)</td><td>1959 (2003 Facade /2008 HP)</td><td>1973 (facade ref 2000 / shell ref 1995)</td><td>1994 (boiler replaced / chiller changed)</td><td>2004 (Minergie)</td><td>1980 (2009 facade renov)</td></tr>
<tr><td colspan="3">Workers</td><td>302</td><td>303</td><td>276</td><td>688</td><td>320</td></tr>
<tr><td colspan="3">Area (EBF) in m²</td><td>7 462</td><td>10 506</td><td>9 750</td><td>12 610</td><td>5 700</td></tr>
<tr><td rowspan="7">Envelope</td><td rowspan="5">Walls</td><td>Components</td><td>U-value (W/m² K)</td><td>0,335</td><td>1</td><td>0,38</td><td>0,15</td><td>0,3</td></tr>
<tr><td rowspan="4">Windows</td><td>U-value / operable ?</td><td>1,1</td><td>3,3 / not operable</td><td>1,9 / open during lunch if T>18</td><td>0,8</td><td>0,6</td></tr>
<tr><td>area in %</td><td>35</td><td>45</td><td>70</td><td>60/10/30</td><td>50</td></tr>
<tr><td>store (ext/int)</td><td>some (exter)</td><td>internal</td><td>exter</td><td>Exter</td><td>Exter</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Roof</td><td>Components</td><td>U-value (W/m² K)</td><td>0,3</td><td>0,51</td><td>0,51</td><td>0,15</td><td>0,3747</td></tr>
<tr><td>Floor</td><td>Components</td><td>U-value (W/m² K)</td><td>0,3845</td><td>0,8</td><td>0,21</td><td>0,161</td><td>2,6976</td></tr>
<tr><td rowspan="5">Systems</td><td rowspan="3">Heating system</td><td colspan="2">Energy carrier</td><td>District heating</td><td>District heating</td><td>Gas(97%) and Oil (3%)</td><td>District heating</td><td>District heating</td></tr>
<tr><td colspan="2">Efficiency (%)</td><td>90</td><td>90</td><td>95</td><td>95</td><td>90</td></tr>
<tr><td colspan="2">Insulation (mm)</td><td>10</td><td>10</td><td>20</td><td>20</td><td>10</td></tr>
<tr><td rowspan="2">Cooling system</td><td colspan="2">Energy carrier</td><td>Electricity</td><td>Electricity</td><td></td><td>District heating</td><td></td></tr>
<tr><td colspan="2">Efficiency</td><td>80</td><td>80</td><td></td><td>95</td><td></td></tr>
<tr><td>Ventilation</td><td colspan="3">Humidification / pre heating…</td><td></td><td></td><td>Humidification</td><td>Humidification and pre-</td><td>De-humidification and air</td></tr>
</table>

					heating	conditioning
	Heat exchanger	Yes, with 60% efficiency				
	Air flow (m3/h)	197 195	41 550	192 267	37 970	15 777
Comparison	LESOSAI Heating final energy (MJ/m²)	205,9	375,9	374	214	447
	DATA Heating final energy (MJ/m²)	162,3	311,5	268,1	132	410
	Demand / consumption in %	126,9	120,7	139,5	161,7	109,0
	LESOSAI Electricity consumption (MJ/m²)	930	550	317,2	168,8	150
	DATA Electricity consumption (MJ/m²)	857,2	1080	315	584	557
	Demand / consumption in %	108,5	50,9	100,7	28,9	26,9
	Solar gain / solar radiation (%)	17	37	35	25	25
	Ventilation m3/hm²	7,263	2,805	4,32	0,62	2,82
	Internal gains (W/m²nbpiece)	47	35	34	129	18
	Windows	Windows operable 5° during lunch time if >18°C and some always during lunch time		window open during lunch if Text>18°C	With night and week end reduction of the ventilation the result doesn't match	
	Others	Night cooling when Tmax>26 °C			Windows are not operable	Windows are not operable

As all the buildings have been refurbished, it is not possible to accurately compare them to know which one should have the highest consumption according to the year of construction. What is interesting to see here is the matching between calculated and measured value.

3.2 Sensitivity of the results

It is essential to know the assumption's choice impacts on the result; indeed some of the parameters have a huge impact, and other have almost no influence. By evaluating all the parameters impact, it makes sure that the chosen assumptions won't degrade the relevance of the results.

Table 3.2 Main information needed by the software and their impact on the energy consumption.

Parameters				Impact on LESOSAI calculation in % of the final energy consumption
Use	Year of construction (and refurbishment)			
	Operative temperature (summer and winter)			10
	Week-end and night reduction for temperature demand?			7
	Internal gains	Electric devices: kind and number of computer		40
		Number of worker		10
		Specific light power		30
Envelope	Walls	Components	U-value (W/m²K)	
		Windows	U-value / operable?	5
			store (ext/int)	2
	Air tightness (and wind exposure)			8 to 27
Systems	Heating system	Energy carrier		3 to 23
		Pipes insulation		10 to 100
Ventilation	Regulation type: speed, day/night, hours			10
	Mechanical or natural ventilation / windows open			-20 to +30
	Intake / Exhaust: distributed airflow (m3/h)			13 (for +40% airflow)
	Ground-coupled heat exchanger or heat recovery (%) ?			7
	Specific fan power (W/(m3/h))			1

3.2.1 Ventilation system

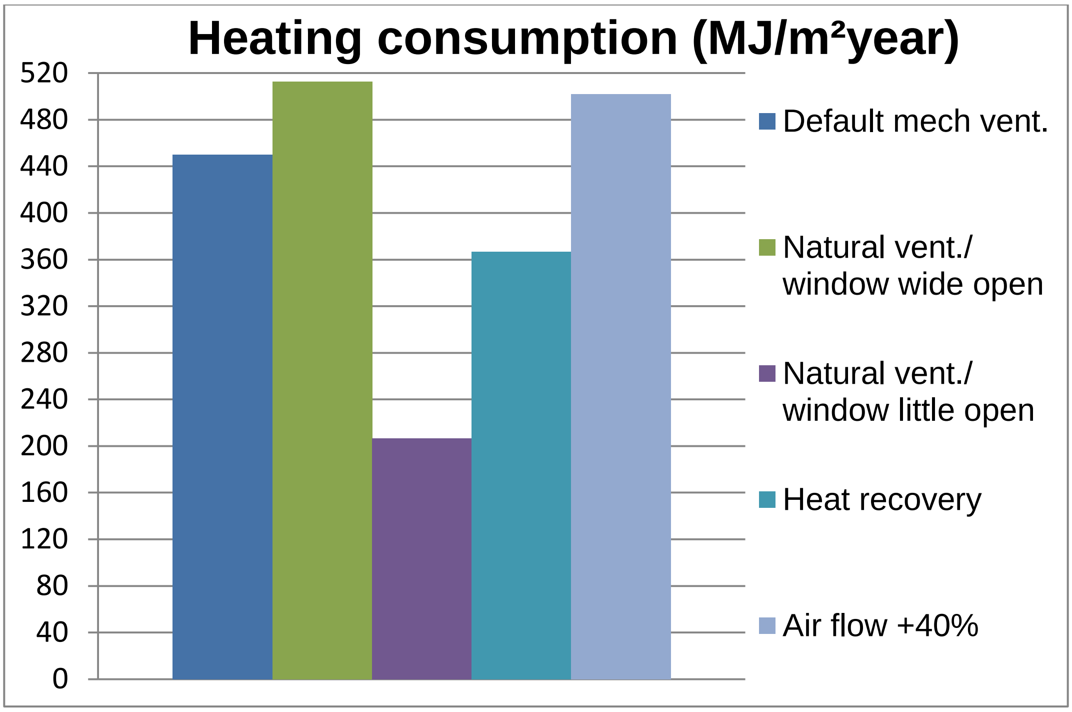

Figure 3.4 The impact of the ventilation system on the heating consumption

Table 3.3 Consumption increased or decreased percentage compared to the basis.

natural ventilation/ window wide open	Natural ventilation/ window little open	Heat recovery	Air flow +40%
+5,6	-16,2	-10,9	+7,7

The basis variant is a building with ordinary ventilation, at default flow and without energy recuperation.

When windows are opened in a variant, it is 1h during lunch, every day, even if it's cold outside. Windows can be open from 5° to 90°, we try both extreme possibilities.

The ventilation system only affect the heating needs, the cooling needs (always around 1.5 kWh/m²y) and the electricity consumption are constant.

The conclusion of this basic test is that the windows operability has a significant impact on the heating consumption.

3.2.2 Internal gain

The given information is not very precise concerning the facilities. However, according to the literature, light electricity should consume around 26 kWh/m²y and devices electricity 40 kWh/m²y (Enertech, 2004) even if the report is 10 years old, the number should be close to this value, indeed, if the energy efficiency of the devices is rising, workers tend to use more and more devices (such as two screen as you can see in the picture below, taken in one building partner of the project). The results from Enertech also match with SIA380/4 values.

Figure 3.5 Use of two screens for on desktop.

The impact of the internal gains on the total primary consumption is not important, but it plays on the balance between electricity and heat consumption. As expected the heating consumption decrease when the devices consumption increase and vice versa for the cooling consumption. But the total primary energy consumption rise is mainly due to the electricity consumption from the devices.

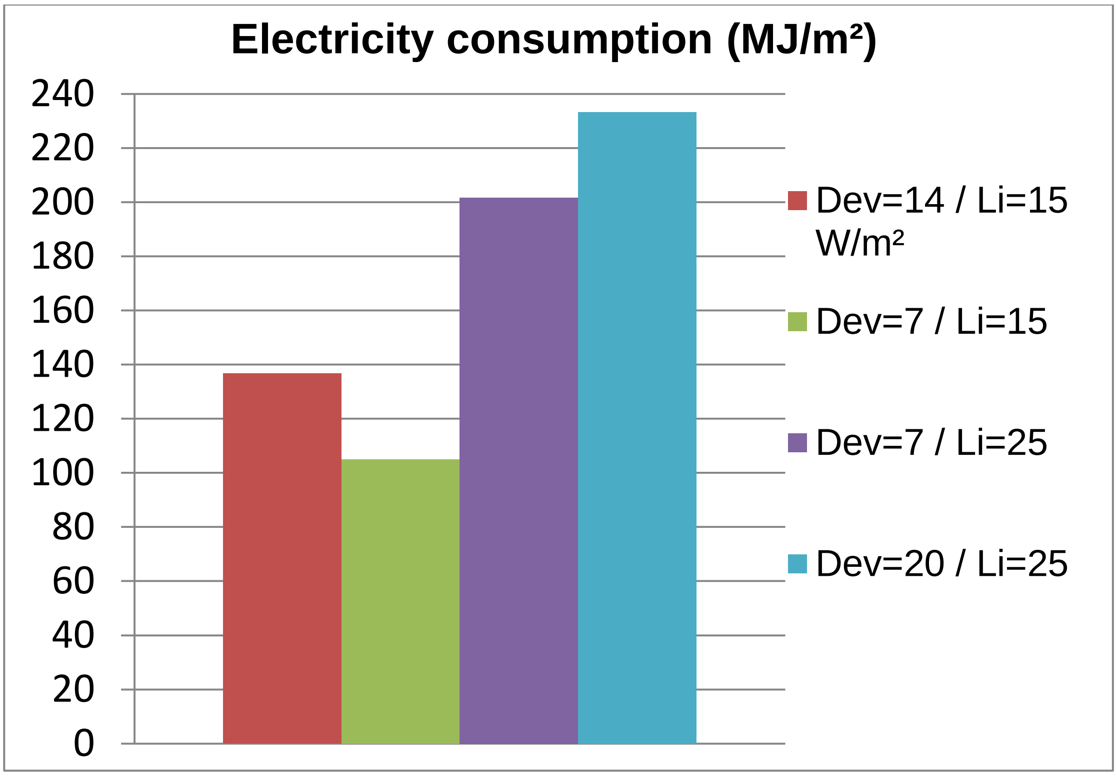

Figure 3.6 Computer equipment and light impact on the electricity consumption.

According to the literature (Enertech), the mean specific light power is 25W/m² in open offices with more than 100 people and 20 W/m² in single offices. This figure varies with the quality of the luminaries and the light bulbs used.

The default value for devices consumption in LESOSAI is 7 W/m² in an office, the mean value according to Enertech is 14W/m².

These parameters have an important impact on the electricity consumption, from the "low" scenario" to the "high" scenario, there is the consumption doubles.

Another factor in office building is the server room and the printer room, the specific power in a server room is 500W/m² in LESOSAI's default parameters, which induces high consumption evolution.

3.3 Comparison of assumed/given and simulated results

In the following part is presented the comparison between the calculated and measured energy for the building sample. One graph represents only the heating consumption over one year and the other represents electricity consumption. The cooling consumption is included in the electricity one, because most of the time, the energy carrier for cooling is electricity.

Figure 3.7 Heating final energy (kWh/m²year) comparison between measured and calculated values.

What is remarkable in this graph is first that the values are matching quite well, and the relation is always in the same way: the measured heating consumption is smaller than the calculated one.

The possible causes of this may be:

- the approximation of U-value is too pessimistic
- the operative temperature is lower in the workspace
- the heating/ventilation regulation is more accurate
- the real systems are more efficient (radiator and boiler)
- the internal gains are higher

The thermal bridges of the envelope have not been taken into account, so even if the U-values are pessimistic, the simulated envelope isn't likely to be under-estimated in terms of insulation.

Then the default operative temperature is 21°C in winter, which is quite reasonable compared to what is often observed (sometimes 23°C have been measured inside the workspace, in wintertime).

Concerning the efficiency of the systems, their maintenance and the regular congestion of radiators with furniture, it's not probable that the efficiency has been under-estimated (the chosen pipes insulation, which has a great impact, is 10mm).

The main remaining most plausible reason is the internal gain load that is higher than expected.

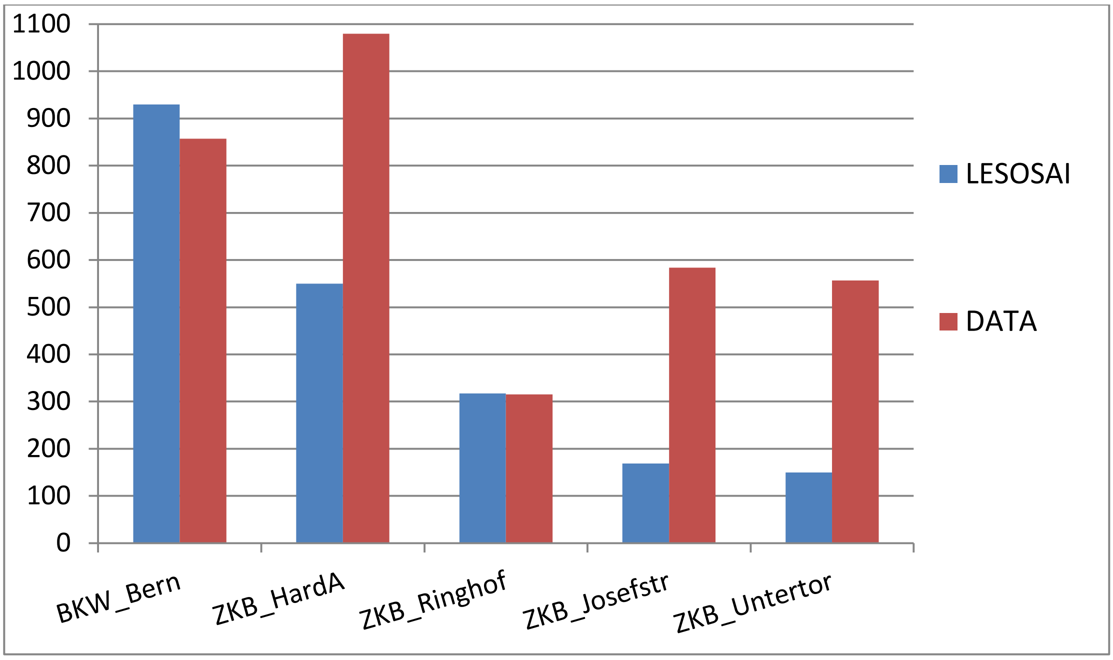

Figure 3.8 Electricity final energy (kWh/m²year) comparisons between measured and calculated values.

There is no obvious correlation between the results of the five buildings; however, the calculated electricity consumption is often lower than the real one. The correlation shows huge differences in this case.

The cause of the gap between measured and calculated values is mainly the lake of information about the equipment and its use.

An increase of the electricity consumption in the software model will leads to a diminution of the heating consumption, the results are thus reasonable.

4 Conclusion

If you would design your own house, you first think about what you need by considering how you live and what habits you have. Then you think about your constraints (cost, available area…). The aim of building is to host people in a comfortable way. But most of the time it is not the one who will live inside who design the building, then the user has to adapt himself, to be comfortable, and this requires often actions on the building’s systems that will change the building performance. So the building and the user work together and each one impact on each other.

As car consumption differs from one driver to another, so is it for building. Software is convenient and enables to have an idea of the energy consumption of a given building quickly and without any big cost demand. But it remains hard to represent the real way of operating the building and that’s even truer for an office building since there are many users with different habits. And it requires a lot of work of observation on the building site to have a precise idea of the use of the building. Nevertheless, added to the improvement of the building’s technologies, the user’s behaviour should also be considered furthermore and bettered.

5 Discussion and outlook

5.1 Critical discussion on the results achieved

The main critical point in the applied method is that the given data are adapted in order to fit with the software requirements, a better solution would have been to send a questionnaire based on LESOSAI's requirements.

Also it would have been interesting to go in situ to observe the comportment of the employee, because when you ask question, the answer can differ from what is really done. However the duration of the project was too short.

Moreover they were some missing parameters, such as thermal bridges which are hard to determine but have an impact on the result.

Nevertheless, the calculated results remain quite realistic: in an average the difference between measured and calculated energy consumption is 30% for heating and 40% for electricity and for two building (Bern and Ringhof) both results are matching well.

5.2 Outlook

To better the project results and conclusion, it would be first necessary to run more building's simulation to have a better correlation between measured and calculated values.

Then, it would be useful to have a depth investigation concerning all the electric facilities, such as lighting, printers and computers, in order to know the exact number per room and their power consumption. The same should be done concerning the opening of the windows and curtains shut down.

It would also be interesting to repeat the calculation on different software, which may need slightly different parameters to be entered.

In order to accelerate the taking into account of users when designing a building, it would be good to create a database with basic habits, depending on the policy of the company. Hopefully the software's programmer will soon add an easier way of modelling the user's impact.

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