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A case study on the extension of the Regional Medical Center Wiener Neustadt, Lower Austria

Evaluation of simulated energy efficiency in contrast to the actual building performance

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Dedicated to my mother, father, Afrdita, Sacir, and Simone

The origin of "Sustainability" is a concept from the forestry of the 18th century, which means: do not chop more wood down, than can be replenished.

Since the 1980s this word stands for holistic, long-term oriented thinking.
It is all about ensuring the survival of mankind by using the current generation to behave in such a manner, that the future generation will not be affected by our actions.
<Donovan Finn 2009>

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Abstract

The present research evaluates simulated and intended energy consumption in contrast to the actual building performance. By using dynamic simulation the actual heating and cooling demand of a building could be predicted so that an adequate building services system could be chosen. By using the appropriate system, higher cost efficiency in building performance can be achieved with an overall lower environmental impact.

A case study on the extension House B of the Regional Medical Center Wiener Neustadt (MCWN), Lower Austria was carried throughout a six months period.
With the dynamic simulation software EDSL Tas, the new wing was modeled in the 3D-Modeller application and imported with all its building elements, floors and zones into the Building-Simulator. Weather data used for TAS simulation was provided from Wiener Neustadt's Airfield weather station by ZAMG. Parameters as global radiation, diffuse radiation, cloud cover, dry bulb temperature, relative humidity, wind-speed and wind-direction were included in the weather file.

The combination of 3D-Modell, building elements, internal conditions and weather data enables a realistic dynamic simulation, which calculates the heating and cooling demand for a period of six months. Monitored data of actual energy consumption was made available by the hospital´s administration in order to compare it with the intended (Energy Certificate) and the simulated results.

The objective of this research is the comparison of actual and theoretical energy demand. Based on the results the necessity of building simulation in the design phase of the health care system is discussed.

Zusammenfassung

Die vorliegende Arbeit evaluiert einerseits den simulierten andererseits den geplanten Energieverbrauch im Gegensatz zur tatsächlichen Energieleistung eines Gebäudes. Mit der dynamischen Simulation, können Heiz und Kühlbedarf so berechnet werden, sodass dementsprechend die passendes technische Gebäudeausrüstung gewählt werden kann. Dies ist nicht nur umweltschonender, sondern auch kosteneffizienter.

Als Fallbeispiel wird mit der dynamischen Simulationssoftware EDSL Tas, im Zuge der Diplomarbeit der Zubau des Landesklinikums in Wiener Neustadt, Niederösterreich detailliert als 3D-Modell aufgebaut und anschließend im Softwarepaket enthaltenem Gebäudesimulator mit den entsprechenden Baumodulen, Bauelementen und konditionierten Zonen importiert. Die stündlichen Wetterdaten der nächstgelegenen Wetterstation am Flugfeld Wiener Neustadt, werden von der ZAMG zur Verfügung gestellt. Parameter wie Windgeschwindigkeit, Windrichtung, relative Luftfeuchtigkeit, Globalstrahlung, Temperatur, Diffus Strahlung und Bewölkung werden in eine für Tas kompatible Wetterdatei konvertiert.

Die Kombination von Wetterdaten mit dem 3D-Modell erlaubt somit eine realitätsnahe dynamische Simulation, die den Energieverbrauch des Gebäudes für die Zeitdauer eines halben Jahres, im Stundenintervall errechnet und graphisch darstellt. Die erforderlichen Daten über den effektiven Energieverbrauch werden von der Gebäudeadministration für die Diplomarbeit zur Verfügung gestellt, um diesen mit den Resultaten des Energieausweises sowie der Simulation zu vergleichen. Ziel der Diplomarbeit ist eine Gegenüberstellung vom tatsächlichen und theoretischen Energiebedarf. Aufgrund der Resultate wird die Sinnhaftigkeit einer Gebäudesimulation im medizinischen Sektor vor Baubeginn eines Projekts diskutiert.

1 INTRODUCTION

1.1 Motivation

In 2008, the Regional Hospital Holding of Lower Austria (LA) started adapting and retrofitting hospitals all over the province for optimization. One of those hospitals was The Regional Medical Center of Wiener Neustadt (MCWN), one of the biggest in LA. A recent study on this hospital suggested that a refurbishment would be less cost efficient than the construction of an extension. The authorities proceeded on building an extension to the existing hospital, called House B and in October 2011 the project was completed. A completely new hospital will be built in a couple of years in the periphery of Wiener Neustadt to facilitate the transport connection and bring relaxation to the city center, but until then the main building and House B will provide the necessary medical assistance to the local population.

Due to economic factors of a building, it is important to accurately predict energy consumption, operating costs and occupancy comfort before starting a project. In contemporary society, architects, building physicists and engineers are using knowhow in combination with simulation tools to optimize their projects, in regard to lifecycle costs, energy-efficiency, carbon dioxide footprint plus a wide variety of other factors. Still the dynamic thermal interaction, that comprises of occupancy levels, outdoor climate, heating/cooling and the structure itself is yet difficult to quantify.

Hence this study sought to investigate the differences and similarities between intended, actual and simulated heating and cooling demand of the extension House B, using the software EDSL Tas.

1.2 **Objectives**

Before constructing the extension of the hospital in module style system, an Energy Certificate (EC) was done to predict the energy class of the hospital. Later on it was compared with the measured data from the sensors that monitor the consumed energy for heating/cooling demand in 15 minutes tact, since commissioning date.

Furthermore simulation scenarios that generate hourly values were conducted to compare actual, intended and simulated demands. In order to investigate the differences and similarities of the demands, three simulation scenarios were performed with the software EDSL Tas. First scenario was simulated with values according to the Austrian standards, whereas the second one considered calculated real data parameters as internal conditions, operating time and the actual weather. For the last scenario, parameters of the EC were used. Figure 1.1 shows the hierarchy of the conducted steps of the different simulation scenarios.

Different standards and parameters were used for steady state and dynamic simulations. The resulting outcomes were analyzed and discussed in detail. One question would be if a comparison of actual, intended and simulated demand does make sense in order to have a sustainable building performance. Another question that arises is which simulation parameters have the greatest impact on the heating and cooling demands and what would the difference be between intended and simulated energy performance. These are some of the questions that need to be answered in order to come to a better understanding of which simulation scenario will perform better.

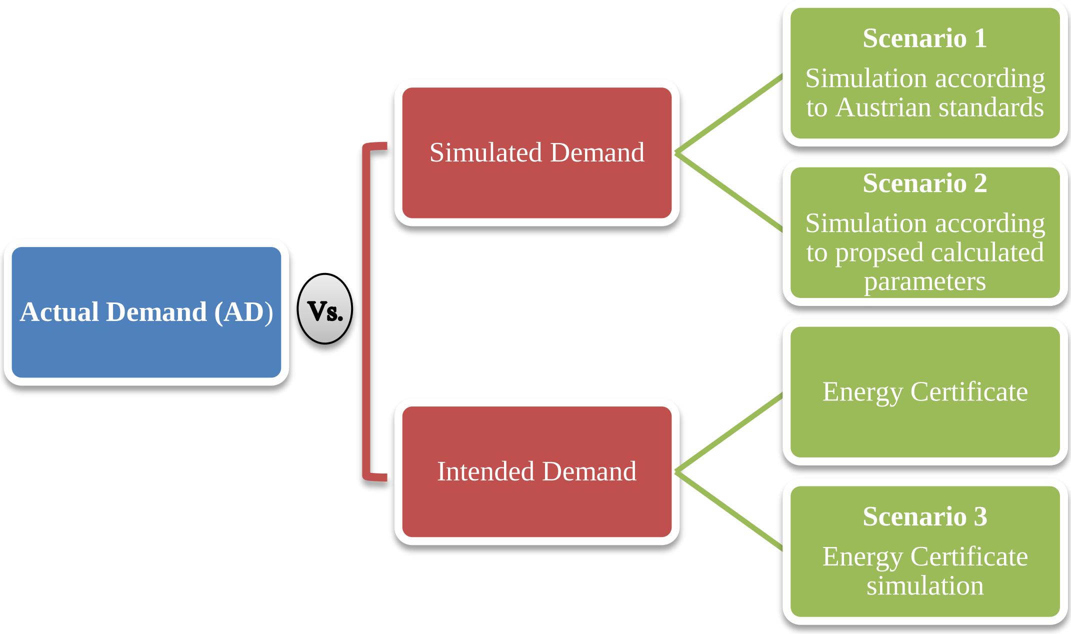

Figure 1.1: Hierarchy of the performed simulation scenarios 1 - 3

There may be several alternative options to achieve the objectives mentioned above. However, computer simulation is in contemporary society one of the most powerful tools for the analysis and design of complex systems, as Aburdene (1988) declares:

"Simulation is the process of developing a simplified model of a complex system and using the model to analyze and predict the behavior of the original system.
Why simulate? The key reasons are that real-life systems are often difficult or impossible to analyze in all their complexity, and it is usually unnecessary to do so anyway. By carefully extracting from the real system the elements relevant to the stated requirements and ignoring the relatively insignificant ones (which is not as easy as it sounds), it is generally possible to develop a model that can be used to predict the behavior of the real system accurately." (Aburdene 1988, p 15)

1.3 Background

Nowadays, almost 50% of the total energy consumed in Europe is used for generating heat for either domestic or industrial purposes. On the one hand, the biggest share of this energy is produced through the combustion of fossil fuels such as oil, gas and coal with a damaging environmental impact arising primarily from the associated greenhouse gas emissions and also from the resource extraction process. On the other hand, cooling is, with few exceptions, achieved by processes driven by electricity, which is still also predominantly produced from fossil fuels (Kema et al. 2011). Because of the yearly rising energy costs, the reduction of energy use, not only in Austria but all over the world, has become one of the most important issues.

For the past 50 years, a wide range of building energy simulation programs have been developed, enhanced and are in use throughout the building energy community for improving and predicting the energy usage of old and new buildings. The favored core tools in the building energy field are those which provide users with key building performance indicators such as energy use, energy demand, lighting, shading, acoustics and (life-cycle) cost aspects. This bandwidth of simulation tools supports the user to analyze projects from the design through construction and maintenance stages (Crawley et al. 2008).

Using thermal simulation tools, heating and cooling demands of buildings are anticipated. Both the thermal building simulation and thermal system simulation are tools of integral planning and require intensive communication between all parties involved in planning. Compared to common planning procedures of HVAC systems, the simulation simultaneously considers the interaction between the system, building construction and its maintenance.

In contrast to the common steady state simulation with simple static algorithms, for the dynamic simulation there have been developed some fundamentally different computational methods. The mathematical established answer of dynamic simulation tasks is based on the solution of problems with finite differences (Ployer 2006). The heat conduction processes in a wall e.g. are calculated considering each individual wall layer. Calculation steps, performed by the computer, provide then an overall picture of the heat flows and temperature gradients in the wall.

Figure 1.2: Overview of basic building simulation software features (Crawley et al. 2008)

Most of the commercial software packages deal with modified versions of the last mentioned methods. Another interesting method developed by Beuken (Schinnerl et al. 2002) uses the analogy of electrical engineering and replaces building components with electrical circuits. Thermal mass storages are compared with electrical capacitors. Instead of thermal conductivity, the electrical conductivity is calculated. Hence the current flow results are interpreted as heat flow outputs. Thus the diverse algorithms and software packages generate slightly different results. These procedures are in fact just mathematical models for describing the reality as accurate as possible.

In Austria, dynamic energy performance simulations are not as common as the widely spread steady state calculated Energy Certificates, which are mentioned in standards and laws as in the Energy Performance Certificate Law of Austria (EVAG) and the Austrian Institute of Construction Engineering (OIB6). Since December 2012 owners and landlords have to provide their customers with an EC not older than 10 years, that includes the heating demand and the overall energy efficiency factor of properties, otherwise pay a penalty of 1.450 Euros (Energy Performance Certificate Law of Austria 2010). Furthermore, for all non-residential buildings with a conditioned gross floor area of over 500m², the first two pages of the certificate have to be displayed in the main entrance area.

The heating demand is the amount of energy that the heating system produces in order to heat all conditioned spaces, whereas the cooling energy demand determines how much energy is required to cool a building to a defined temperature during the hot months, both expressed by the unit "$kWh \cdot m^{-2} \cdot a^{-1}$" (Pöhn et al. 2012).

In Austria one must include the gross floor area of heated and cooled rooms when considering computational calculations, and not necessarily all areas of a building like unconditioned staircases or basements. The peak values and load profiles of heating/cooling loads of buildings are the basis for the sizing and selection of HVAC equipment and systems (Hong et al.2000).

The heating/cooling demand is calculated according to the standards ÖNORM B 8110-5 and 8110-6.

For calculating the energy performance of a building, the following thermal balance equation is used:

$$Q_h = (Q_T + Q_V) - \eta \cdot (Q_I + Q_S)$$

[Equation 1.1]

Q_h	Heating Demand [kWh·m^{-2}·a^{-1}]
Q_T	Transmission heat losses [kWh·m^{-2}·a^{-1}]
Q_V	Ventilation heat losses [kWh·m^{-2}·a^{-1}]
Q_I	Solar gains kWh·m^{-2}·a^{-1}]
Q_S	Internal gains [kWh·m^{-2}·a^{-1}]
η	Utilization factor

All these parameters are applied in both steady state calculations, such as the Austrian Energy Certificate, as well as in dynamic simulations.

Nowadays, many researches deal with the reduction or prediction of energy consumption in the building sector, relating to heating and cooling demand. Since the 1970s the approach to energy performance was developed from a "passive" calculation to an "active" one for aiming energy optimized building design. According to a recent research of a non-residential building in Germany, calculation procedures according to DIN V 15599 were compared with a thermal building simulation by Zerwas et al. (2008). In this case the Energy Certificate was only close to reality with simple buildings, whereas the simulation could also manage complex structures.

Ulrich P. (2011) compared the heating performance of eight residential buildings in Vienna by different calculation methods as steady state (annually) and dynamic simulation (hourly). His results showed that the design process can be accomplished by using a more sophisticated procedure, that of the dynamic simulated method. Thus proving that the Energy Certificate is just a determination of the energy index of a building.

Another research dealing with the user and system assumptions on energy simulation considered the necessity of effective central control of building systems and the critical importance of human behavior (Kiesel et al. 2010). Standards typically use highly simplified calculation methods and crude human behavior values for an accurate energy performance calculation, therefore internal gains, occupancy level and ventilation should be more realistic or empirically based. Also Leimer (2011) mentions that despite very precise mathematical formulas, building simulation can only approximate the results. The outcome has always to be looked at in connection with the boundary conditions and assumptions that were made. In reality the user behavior adapts with the different internal and external environmental conditions. For this reason, dynamic simulation results should be considered as variant calculations for improvement purpose.

2 METHOD

2.1 Regional Hospital Holding of Lower Austria

Hospitals, as central organizations in the health care system have an essential contribution to public health. Austria attributes enough resources to its health system but not enough attention is being paid to the sustainability of the building services. One can assume that there is a large and realistic potential for improvements in existing and future hospitals.

From 2004 until 2008, the Regional Hospital Holding of Lower Austria (RHHLA) located in St.Pölten, took over the management of the province hospitals, clinical training centers and nursing schools in Lower Austria. This included maintenance, medical standards, optimal nursing care, patients' accommodation and modernization of the building structures.

With a total of 27 clinic sites, 170.000 performed surgeries and 2.24 million occupant days (days of hospitalization), the RHHLA is the largest hospital operator in Lower Austria. Thus the Hospital Holding is the central focal point for LA's health care system (LKNOE 2013).

Key facts of the RHHLA:

- In total, the RHHLA provides **8.200 beds**
- Employment of approximately **19.900 people**
- Annually, **385.000 patients** receive health care
- **95%** of Lower Austria's inhabitants can reach a hospital within 30 minutes

Lower Austria, known for its forward thinking, reinvests the way in which renovations and new buildings in passive house standards are done. Sustainability is a main factor in respect to ecological materials used and energy efficient building services. In 2011, nine clinics were being retrofitted and renovation on MCWN started first because of its improper condition. A recent study indicates that until 2021, LA will spend more than two billion Euros for the ongoing projects (Brandecker and Neuwirth 2011).

Figure 2.1: Map of regional hospitals in Lower Austria (LKNOE 2012)

In 1856, the citizen hospital of Wiener Neustadt (WN) was assigned to the Health Care Association of WN and therefore was declared a public hospital. Thirty years later, the opening of the new building, located next to the existing one, took place. The first relevant expansion, including the surgical department with the additional operating theatres, bed and treatment wings began in the early 30s. During the Second World War, the main building was completely destroyed and re-erected until 1949. From 1982, all wards were situated in a new building, except of the II Internal Medicine and Trauma Surgical Ward, which remained in the old structure.

Figure 2.2: Citizen Hospital of Wiener Neustadt in 1856 (Brandecker and Neuwirth 2011)

Today the hospital is a focal hospital of LA, having 15 wards, 4 departments and 2.300 employees. More than 46.000 patients are treated stationary in the 880 available beds.

On the 1 of January 2008, the legal ownership was assigned to the RHHLA. An extension was considered necessary because of the unsuitable conditions of the II Internal Medicine and Trauma Surgical Ward located in House A, until the new hospital in the periphery of Wiener Neustadt will be completed (Brandecker and Neuwirth 2011).

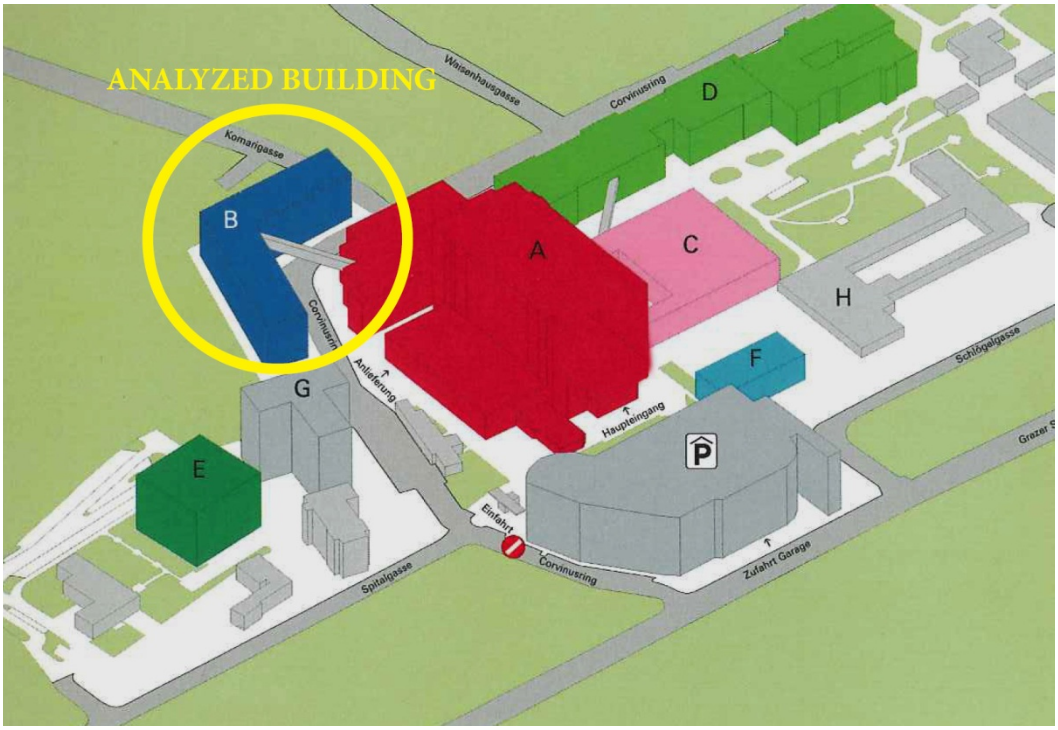

Figure 2.3: Site plan of the MCWN (Brandecker and Neuwirth 2011)

A. Bed wing, East wing, Pavilion
B. **House B (analyzed building)**
C. Emergency department and first aid
D. Old building
E. Pavilion N
F. Pathology
G. Nursing training school
H. Administration
P. Multi storey car park

The city of Wiener Neustadt is just 50 kilometers south of the national capital, Vienna. With a population of more than 40.000, it is the second largest city in Lower Austria. The MCWN is located in the heart of Wiener Neustadt, the inner district, connected via the main road B17 with its neighboring communes (Mertz and Seidl 2005).

2.2 Extension of the regional MCWN (House B)

On the 8th of September 2011 the opening ceremony for the MCWN extension erected in Room Module Style took place. As a unique project throughout Europe, the House B which is the focus of this thesis, consists of 108 prefabricated modules and accommodates the II Internal Medicine and Trauma Surgical ward. This is just a temporary solution that the architects thought of, until the new building of the MCWN will be completed in this decade.

By use of the Room Module System, a completely new building structure was erected in record time. The new medical facilities are situated on an 8.500 m² gross floor area - distributed on four floors, where 180 patients' beds and four operating theaters are accommodated. A total of 29.3 million Euros were invested in the extension for an optimal continuing medical care (Stugeba 2013) .

Figure 2.4: South elevation of the extension House B, Corvinusring (Stugeba 2012)

Hospitals are complex buildings with a large amount of occupants. Doctors and nursing staff have to cope with long distances each day. That is why MCWN's executive company Stugeba designed the new building in collaboration with the staff and so the distances in the extension building are shortened and patient care is optimized.

For the simulation in Tas a building model of the House B was modeled in the 3D Modeler application. In Figure 2.5 the southwest and northeast façade of the building are presented.

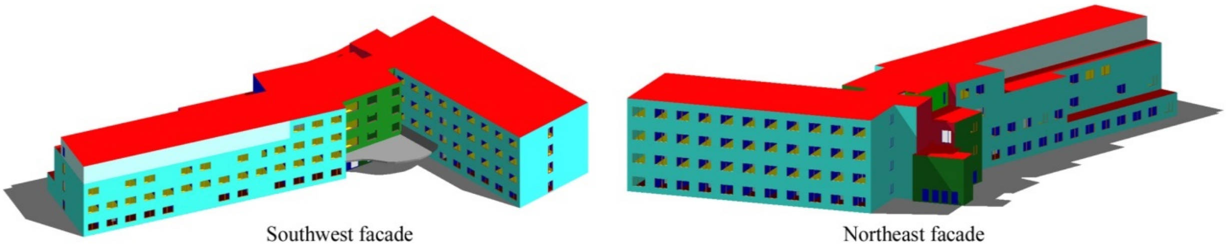

Figure 2.5: Southwest and northeast facade of the extension House B, modeled in Tas

The following pages illustrate the floors and sections of the hospital with all the various functions, colored and explained. More than half of the area is dedicated to the In Patient Ward, whereas the rest belongs to the Out Patient Ward, Operating Theaters and the Building Services Rooms.

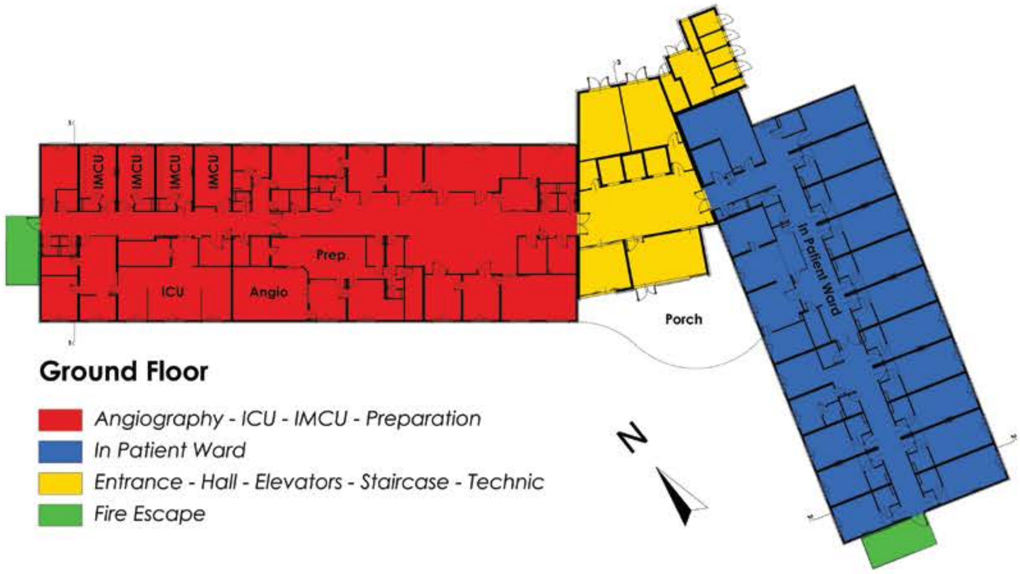

Figure 2.6: Ground floor of House B (Stugeba 2012)

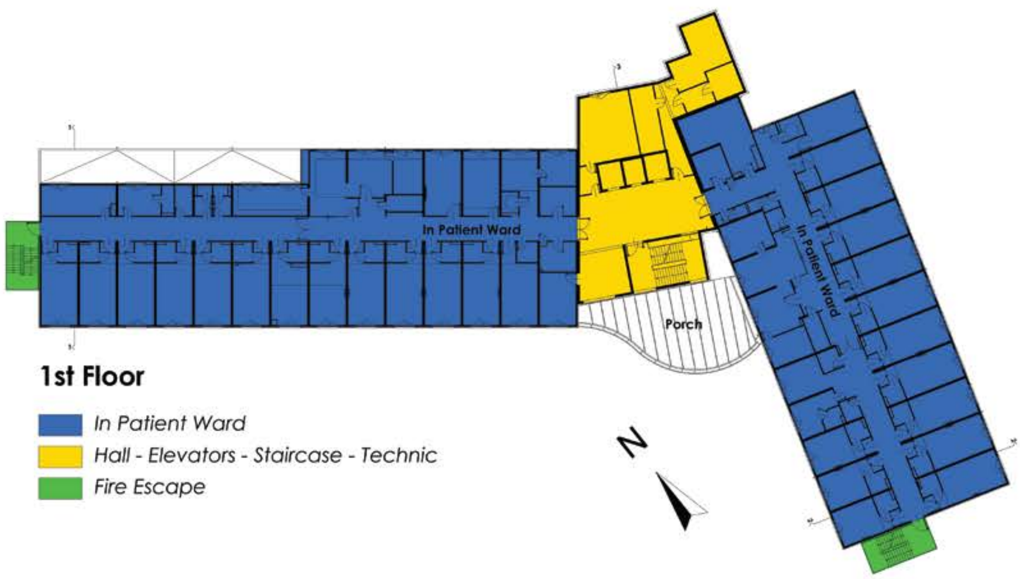

Figure 2.7: First floor of House B (Stugeba 2012)

Figure 2.8: Second floor of House B (Stugeba 2012)

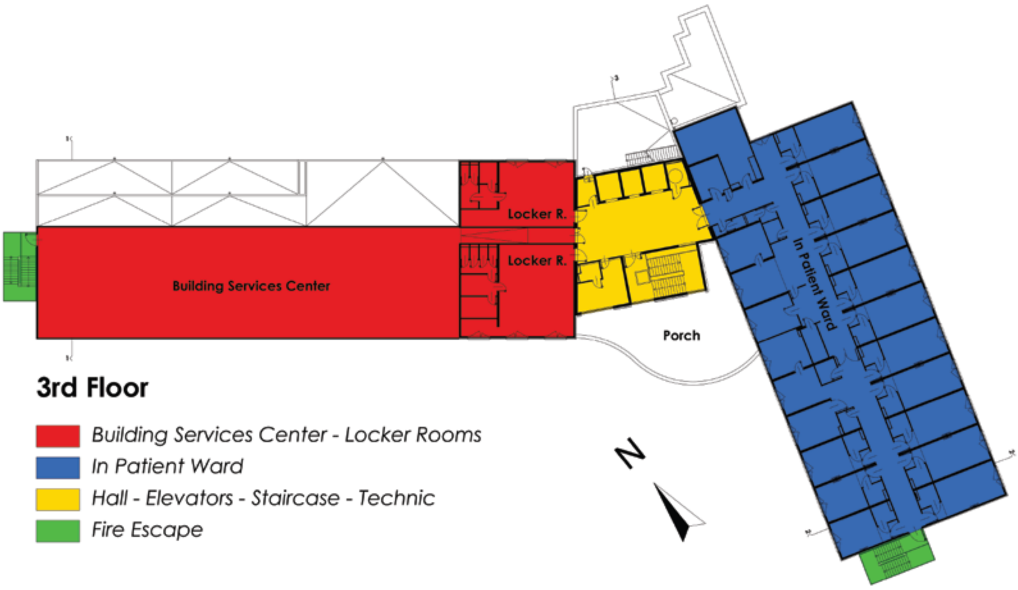

Figure 2.9: Third floor of House B (Stugeba 2012)

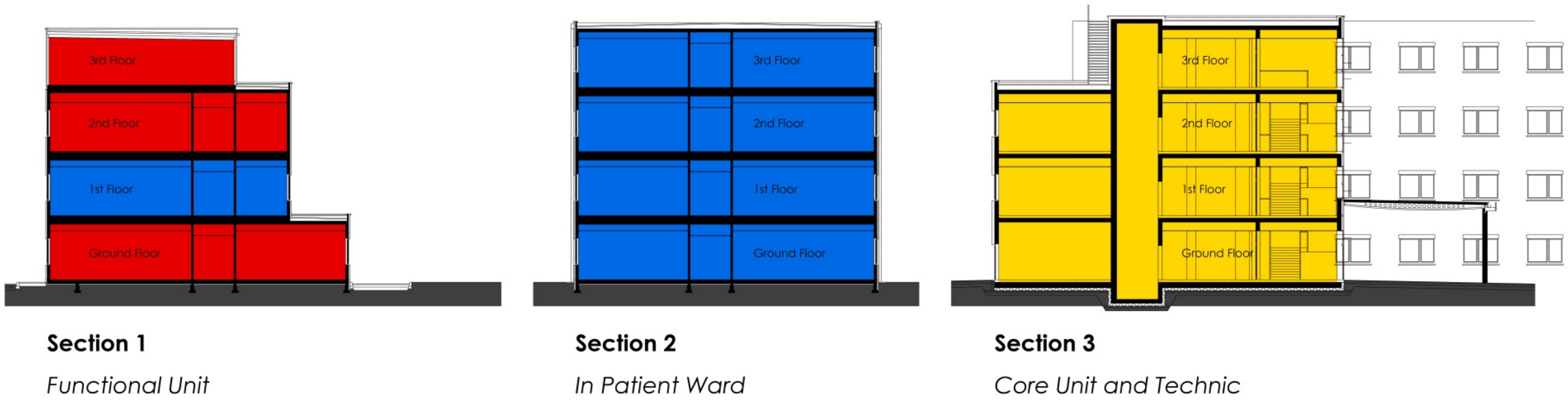

Figure 2.10: Sectioning of House B (Stugeba 2012)

2.3 Module Style System of the House B

Room modules are factory-prefabricated, low energy building units with dimensions up to L x B x H = 18.5 x 4 x 4m. Statically measured steal sections (see Figure 2.11), linked through welding techniques, provide the carrier construction for floors, wall and roof. The individual parts are isolated and planked by means of edificial plaster boards. Through direct factory production it is possible to prefabricate building installations such as heating, ventilation, sanitary plumbing and electrical equipment up to 85%, later on to be completed on site (Stugeba 2013).

Whilst the room modules were under production at the construction company, the groundwork on the site was prepared. Thanks to the advanced room module style, this technique facilitates a cheaper completion of buildings in record time. Furthermore the noise and dust pollution is reduced to a minimum and the construction phase can continue throughout the winter. The dehumidification process of the screed can be completed at the factory, which enables a faster use of the building.

STUGEBA, the Carinthian executing general contractor of the MCWN, prefabricated 108 modules, which have been transported by flatbed trucks to the building site and enclosed to the reinforced concrete core. After the modules were assembled with a truck mounted crane into one complex, the upgraded insolation was attached to its exterior. This way buildings constructed in Room Module Style can always be extended vertically or horizontally, if needed.
(Brandecker and Neuwirth 2011)

Figure 2.11: Room Module Style scheme (Stugeba 2012)

2.4 **Sectioning of House B**

The Surgical Ward is one of the biggest trauma departments in Lower Austria, where all physical injuries and post-ops are treated. It has two stations on the second and third floor for its patients.

In many hospitals the trauma stations combine operating rooms and their ancillary rooms into structural units for better management. The same principle applies to MCWN’s extension with its four Operating Theaters located on the same floor as the Trauma Station. The OPRs are very sophisticated in respect to hygiene and building performance thanks to a specific range of building and operating equipment.

Figure 2.12: MCWM’s Operating Room in room module style (Stugeba 2012)

One prefabricated module has a two bed and three bed room with sanitary facilities separated by the corridor. On each level, eleven combined modules compose one wing.

Figure 2.13: Angiography with C-arm X-ray system and two Beds Room in the MCWN extension (Stugeba 2012)

Table 2.1: Ward sectioning of the House B for each floor (Brandecker and Neuwirth 2011)

Floor	Unit	Ward
Ground Floor	Intensive Care Unit	II Internal
	Cardiac Monitoring Unit	II Internal
	Cardiac Catheter Unit	II Internal
	Out Patient Service	II Internal
	II Internal Medicine Ward	II Internal
	II Internal Medicine Ward Station 1	II Internal
First Floor	II Internal Medicine Ward Station 2	II Internal
	II Internal Medicine Ward Station 3	II Internal
Second Floor	Trauma Surgical Ward Station 1	T. Surgical
	Trauma Surgical Ward OP	T. Surgical
	Orthopedic Operation Theater	T. Surgical
	Recovery Room	T. Surgical
	Connection to House A	
Third Floor	Trauma Surgical Ward Station 2	T. Surgical

In Table 2.2 the total gross/net floor area and the volume of the building are presented taken from the company's construction plans.

Table 2.2: Room height, Square meters and volume of the extension House B (Stugeba 2012)

Hospital floors	Room height (m)	Square meter (m^2)	Volume (m^3)
Ground floor	3,88	2179,12	8465,88
First floor	3,48	2081,20	7252,98
Second floor	3,88	2081,20	8085,46
Third floor	4,03	1279,73	5157,34
Total gross		**7621,25**	**28961,66**
Total net		**7366,02**	**24834,04**

2.5 **Description of HVAC**

In this chapter, the building services system is explained in detail for a better understanding of the chosen internal conditions values for the simulation.
Zentraplan, the building services company of the extension House B, designed and installed the Electrical and HVAC systems with the latest technical standards for health care. Specific rooms and wings as the Operating Theaters or the Out Patient Wards have special requirements for heating, ventilation and cooling, which have to be met in order to provide a healthy environment for the occupants. Effective ventilation is recognized as a very important factor in the control of infections, for human comfort and also for energy recovery and system reliability solutions in operating theatres and isolation rooms in hospitals. It has been shown that an efficient heating and air-conditioning (HVAC) installations can control the air quality and aseptic conditions (Balocco 2011). Therefore creating a safe and suitable indoor thermal environment for medical staff, surgeons, and patients is necessary.

The main task of HVAC systems is to renew the inside air with additional preparation. In many cases, especially in the health care sector it is also important to set a room under positive or negative pressure in order to prevent unwanted air currents. The air change is required because of air contamination by gases, fumes and dusts which may cause health damage or interfere with work operations. Furthermore, temperature and humidity have to be within a specific range in all rooms (Recknagel et al. 2012). If the temperature requirements cannot be met just by the air conditioning system, the secondary heating systems as radiators and under floor heating have to be activated as a support system. The outside air has to be filtered at all times.

In winter, heated spaces tend to have dry air, because of the air’s different temperature and humidity correlation properties. At any given temperature the air can only support a limited amount of water vapor. When cooler air is supplied from outside into a room and has to be heated up, the humidity level is much lower as it should be and therefore does not fulfill the comfort requirements. For the cold season, the relative humidity should never get below 30% or rise over 70%, because of mold formation and health risks (Szokolay 2008). To keep the balance between temperature and humidity, the system has to run different processes to provide the interior spaces with the required air temperature and humidity level with high energy consumption throughout the year.

The HVAC system corresponds to the ÖNORM H 6020 and NÖLRG (Niederösterreichische Landesregierung) codes. According to the operating time of the hospital a DCC system (Direct Digital Control) with a factory master control system is used for the regulation purpose and building optimization. Monitored data, default settings, fault indications and other related information, are sent to the communication and control center. The HVAC system is connected to the emergency power supply of the MCWN extension (Friedl 2011).

Table 2.3: Design air change rate and air temperature of the Operating Theaters 1-4 (Zentraplan 2012)

Air mass	m³/h	Air temp	°C
Supply air	4.800	External	-15
Exhaust air	4.000	Supply air heating max.	+24
		Supply air cooling min.	+13

The air conditioning appliance, which is a supply and exhaust air machine without recirculation air support, is situated directly above the operating theaters on the 3rd floor. Through preheated air ducts, the fresh air is treated according to the inside air temperature and then inserted into each operating theater.

To keep the air supply volume consistent, a constant volumetric controller with a hermetical block system was installed. The exhaust air is transported vertically to the rooftop via a duct to the exterior. Besides the constant temperature of 22-26 °C, relative humidity of 30-65% and a maximum sound level of 40dB the air inside Ops has to have a low germ and higher air pressure level than the adjacent rooms. Furthermore the supplied air has to be always cooler than the room temperature to enable a laminar air circulation.

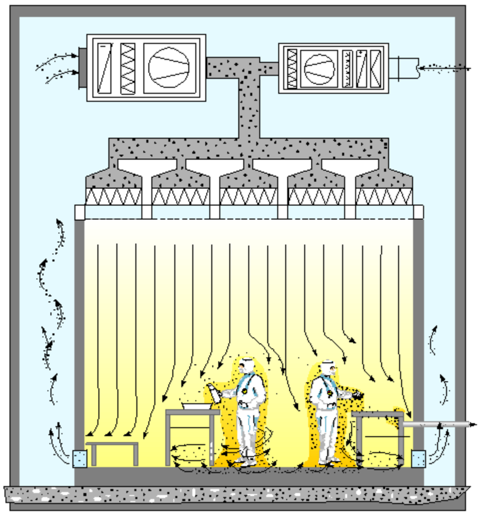

Figure 2.14: Laminar air flow in the Operating Room (Rudolf Simon 2010)

Table 2.4: Design air circulation rate and temperature of the Operating Theaters 1-4 (Zentraplan 2012)

Air mass	m³/h	Air temp	°C
Air circulation	8.600	Air circulation heating max.	+24
		Air circulation cooling min.	+20

In the Operating Rooms the exhaust air is primarily removed up to 75% from ground and 25% from ceiling level, all air discharge openings being provided with lint screens. For each room the fresh air volume amounts up to 1.200m³/h and the recirculating air volume to 8.600m³/h. The sum, 9.800m³/h is generated from the outer stream volume and cooling coil in the air circulation system.

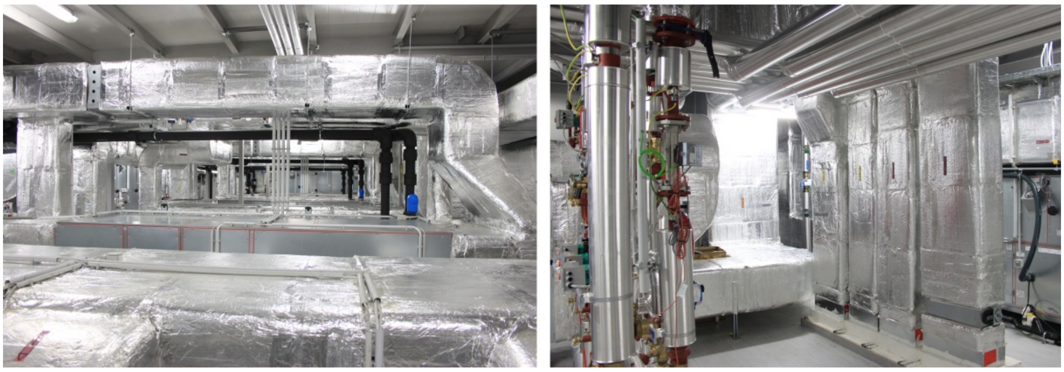

Figure 2.15: Ventilation system of the Operating Theaters 1-4 and the Inpatient Ward

Table 2.5: Design air change rate and air temperature of the Operating Theater's side rooms (Zentraplan 2012)

Air mass	m³/h	Air temp	°C
Supply air	6.200	External	-15
Exhaust air	7.000	Supply air heating max.	+24
		Supply air cooling min.	+18

In the side rooms the exhaust air is primarily removed up to 75% from ground and 25% from ceiling level. Fresh air is supplied through ceiling swirl diffusers or poppet valves. Through preheated air ducts, the fresh air is treated according to the interior air temperature and then inserted into each side room.

Table 2.6: Design air change rate and air temperature of the Outpatient Service and Angiography (Zentraplan 2012)

Air mass	m³/h	Air temp	°C
Supply air	8.690	External	-15
Exhaust air	8.690	Supply air heating max.	+24
		Supply air cooling min.	+18

In the Outpatient Service and Angiography the exhaust air is primarily removed up to 75% from ground and 25% from ceiling level, all air discharge openings being provided with lint screens. Fresh air for the Angiography room is supplied through ceiling swirl diffusers or poppet valves with hygiene outlets and high efficiency air filter Class H13.

Table 2.7: Design air change rate and air temperature of the Bed Units North and East (Zentraplan 2012)

Air mass	m³/h	Air temp	°C
Supply air	23.500	External	-15
Exhaust air	23.500	Supply air heating max.	+24
		Supply air cooling min.	+18

In the Bed Units the exhaust air is removed through ceiling swirl diffusers or poppet valves. Fresh air is spread into the vertical ducts and then distributed to each room. All air ducts have tightness Class C.

The heating plant of the hospital is connected to the district heating system of the EVN network, which has two heat exchangers with an output of **400 kW** each.
The secondary heating plant is equipped with an expansion vessel, required pressure relief valves and other technical safety required equipment. For the hydraulic system separation, a heat exchanger is installed.

Table 2.8: Equipment design temperatures for supply and return flow (Zentraplan 2012)

Radiator	70/50 °C
Under floor heating	45/35 °C
Steam coil for air conditioning	70/35 °C
Water heating	70/55 °C

The heating system distributes the hot water through the main pipe first to the top floor and then the water makes its way down through secondary pipes to all the lower levels.

Operating Theaters, Angiography rooms, Primary Medical Care Units and their adjacent spaces are equipped with floor heating, whereas the Bed Units and the corridors are heated with steel sheeted radiators.

In order to prevent cold air intrusion into the building, an air curtain with a door contact switch is installed in the main entrance area. Moreover all pipes are insulated against heat loss.

The cooling center is located on the ground floor and contains two water cooler units with an overall performance of **586kW**, whereas the required dry coolers are installed on the rooftop. A two pipe system with a supply temperature of 6 °C and a return temperature of 12 °C cools down the building in warmer days.
Chilled beams are used in the Angiography, ICU/IMCU, Ambulance room, Anesthetic recovery room and their adjacent side rooms. For office, technic and multifunctional rooms recirculation coolers are used.

The ventilation system of House B is equipped with cross flow heat exchanging devices. A cross flow heat exchanger transfers thermal energy from one airstream to another in an air handling unit (AHU). Unlike a rotary heat exchanger, a cross flow heat exchanger does not exchange humidity and there is no risk of short-circuiting the airstream. This type of exchanger is used where hygienic standards require that both airstreams are completely separate from one another. It has a thermal efficiency of 40 – 65% (Grundfos 2013).

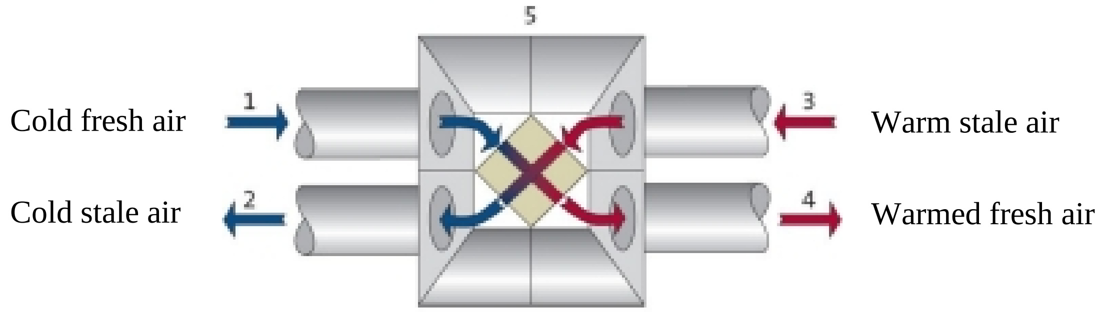

Figure 2.16: Cross-flow heat exchanger (Grundfos Homepage 2013)

2.6 Monitoring system for the actual building performance

Interwatt is a software solutions for an energy management system in accordance with ISO 50001. The established, web-based software IngSoft InterWatt assists companies in different industries and public sectors to optimize their energy consumption, reduce costs and conserve resources (Reese 2008).

The software supports all processes within the scope of energy management. This includes a comprehensive acquisition and analysis of energy consumption data in buildings and production plants. Moreover, the software ensures an automated information flow. This way, the user can keep track of the goals and budgets. Thereby all relevant data sources such as central building control systems and process control engineering, invoices and climate data are used. Out of the heterogeneous data, which is collected in 5 minute up to yearly cycles, a homogenous data structure is generated. This offers a clear overview of the energy costs and consumption of each individual point of consumption (IngSoft Interwatt 2010).

The core part of the system is an internet server, which holds the program`s logic and database. The software is available through any internet browser.

For the data collection the MCWN uses Interwatt as monitoring system which consists of main and parallel sub heating/cooling meters. The hospital administration made all the data they have collected since commissioning date available for this research. The main heating meter measures the energy flow that comes into the building from the district provider, whereas the sub meters measure the actual heating demand. The difference between the readings of these sensors shows the losses that occur in the process.

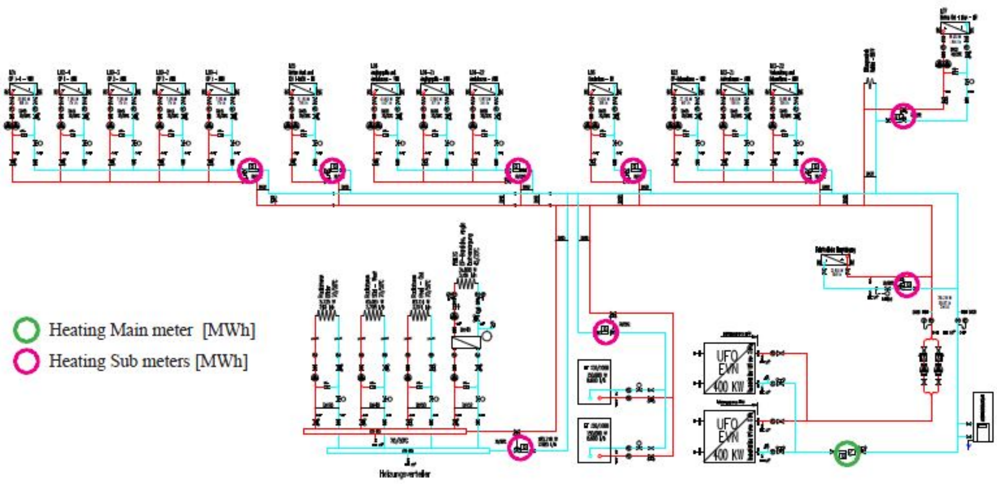

Figure 2.17: Main and sub meters scheme of the heating system (Zentraplan 2012)

The main cooling meters measure the current cooling energy flow, produced by the electrical compression chillers for air conditioning and chilled ceilings.

Again, the differences between the main and sub meters shows the losses in the process.

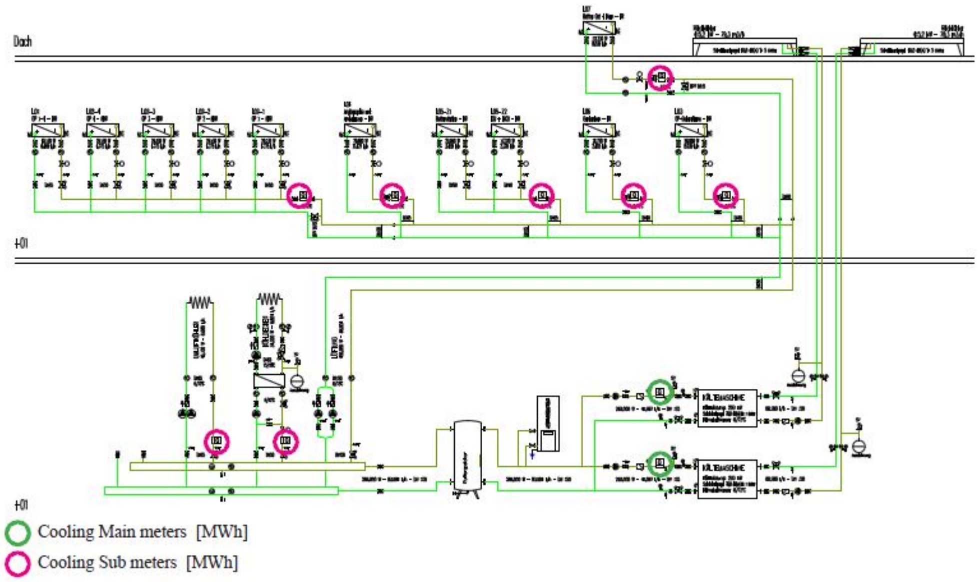

Figure 2.18: Main and sub meters scheme of the cooling system (Zentraplan 2012)

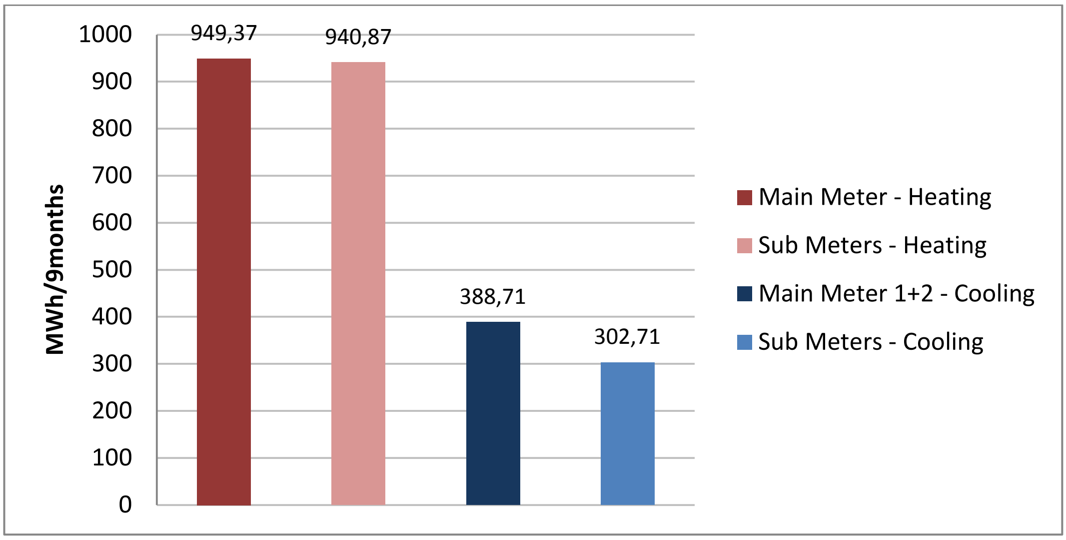

Figure 2.19: Heating/Cooling Meters difference of the actual demand in the House B (Interwatt 2012)

During the monitored period, the difference for heating was 0,9%, which shows the losses in the system, whereas the difference in the cooling process was of 22,12%. For the comparison between actual, intended and simulated heating/cooling demand, the Sub meters' values were used (Figure 2.19).

2.7 Local Climate of WN and Weather File for Tas

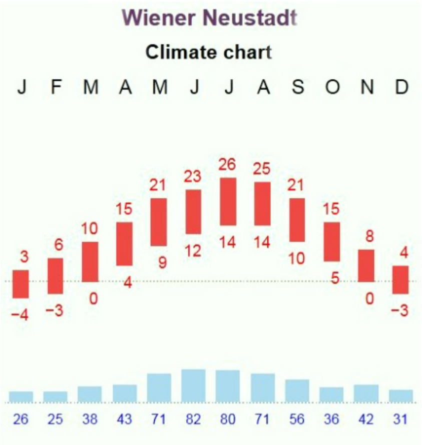

Figure 2.20: Climate chart of WN (ZAMG 2012)

Winer Neustadt has a typically continental climate, (Fig 2.20) with summer months reaching 21–26 °C and winter months reaching a few degrees above freezing point during daytime. Because of its special location in the Stone field area of Lower Austria, WN can have very high temperatures in summer and very low ones in winter (ZAMG 2013).

For the simulation's weather file, data from October 1st, 2011 to June 30th, 2012 was provided by the Central Institute for Meteorology and Geodynamics (ZAMG). The linear distance between the weather station on the airfield of WN and the hospital is about 2 km (Figure 2.21).

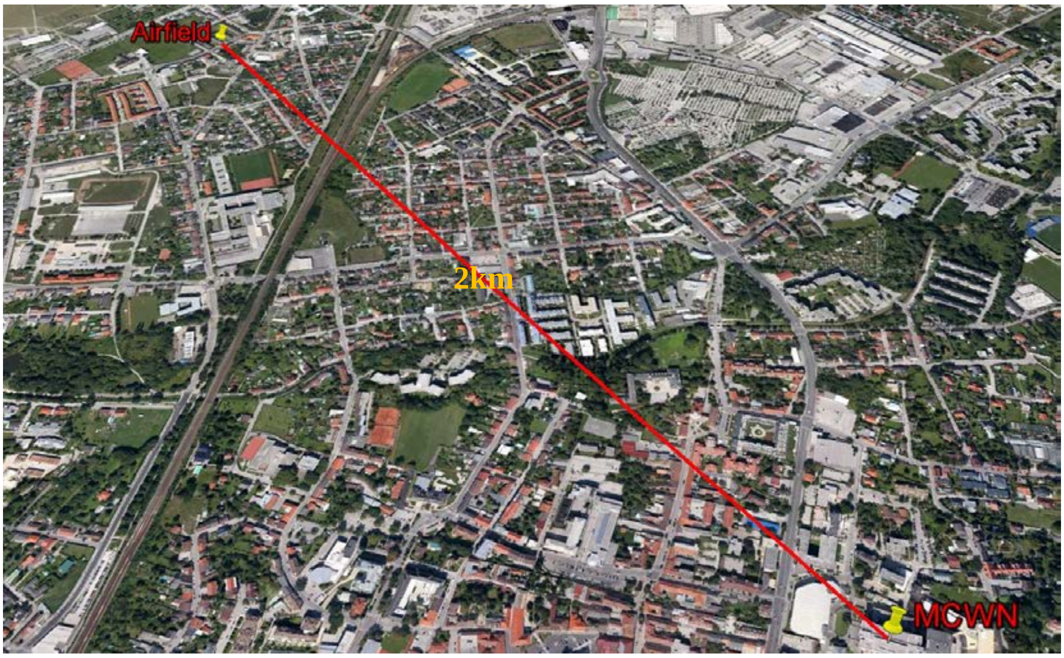

Figure 2.21: Distance between the MCWN and the weather station at the airfield of Wiener Neustadt (Google Earth 2013)

Tas requires weather data on an hourly basis, which are provided by the vendor's website for different locations all over the world. Instead of using the weather file from the website, hourly values (8760 data lines) of Global Radiation, Dry Bulb Temperature, Humidity, Wind Speed and Wind Direction were modified from the original data sets of ZAMG to fit the Tas Macro requirements for generating the Tas weather file. Because, Cloud Cover and Diffuse Radiation could not be provided by the ZAMG, the software Meteonorm was used to calculate the missing data by considering the existing hourly values. Other necessary information for the weather file are altitude, latitude, longitude, time zone and average ground temperature throughout the year, as shown in Table 2.9. In Tas the weather file displays the hourly weather data for each single day in graphical or tabular form. Compared to the EC´s monthly weather data, the hourly weather parameters of Tas are more detailed.

Table 2.9: Relevant weather parameters for generating the Tas weather file

Parameters	Values
Latitude (degrees North)	47,81
Longitude (degrees East)	16,25
Altitude (m)	275
Time Zone (hours ahead of GMT)	+1
Year (A.D.)	2011 - 2012
Mean Ground Temperature in °C	10,33
Global Radiation (W/m²)	Hourly variables
Diffuse Radiation (W/m²)	Hourly variables
Cloud Cover (0-1)	Hourly variables
Dry Bulb Temperature in °C	Hourly variables
Relative Humidity (%)	Hourly variables
Wind Speed (m/s)	Hourly variables
Wind Direction (DegEofN)	Hourly variables

2.8 **Energy Certificate description for the House B**

For this thesis the EC computed with Archiphysik 8 by Hans Baumgartner on 11th May 2010, was analyzed and simulated in Tas. The EC was made available by the hospital´s administration for a comparison between intended and actual heating/cooling demand. In the following pages essential EC parameters will be described.

The Austrian weather file in Archiphysik is separated into 7 climate regions with various sea levels. For the monthly heating/cooling demand calculation the region N/SO - 247m above sea level was chosen as shown in Figure 2.22.

For a comparison between the EC and the Tas weather file the heating degree days and the days which require heating were calculated using the equation 2.1.
The heating degree days, which are the sum of temperature differences between a certain constant indoor temperature (20°C) and the daily average outdoor temperature is in this particular case 3419 Kd (Kelvin day) for the EC. Out of the 273 analyzed days, 239 required heating.
In the Tas weather file the heating degree days amount to 3260 Kd, which results in a 5% difference for the heating demand. Only 199 days required heating according to equation 2.1 thus having 40 days less than the EC weather file.
Table 2.10 presents the calculated heating days for the EC and simulation weather data. The days with an average outdoor temperature above 12°C were not considered as heating days.

$$HDD_{20/12} = \sum^{z} (20 - t_{em})$$

[Equation 2.1] (Pöhn et al. 2012)

$HDD_{20/12}$	Heating degree days for heating limit
z	Number of heating days (meteorological)
t_{em}	Average outdoor temperature of each heating day

Table 2.10: Heating days for Simulation and Energy Certificate Weather file

Month	Heating days SIM	Heating days EC
Oct	24	31
Nov	30	30
Dec	31	31
Jan	31	31
Feb	28	28
Mar	28	31
Apr	22	30
May	5	27
Jun	0	0
Sum	**199**	**239**

Important data for Archiphysik's weather file:

S	Sea level in meters
Θ_{ne}	yearly min. outdoor temperature in °C
T	average outdoor temperature in °C per month
I	global radiation on vertical surfaces

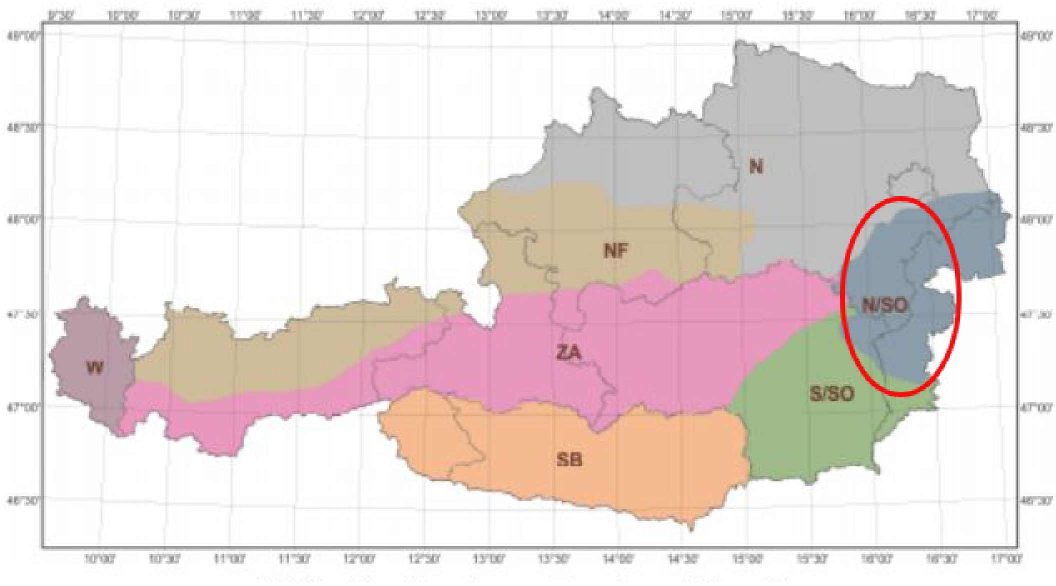

Figure 2.22: 7 climate regions in Austria (ÖNORM B 8110-5: 2011)

The results that Archiphysik provides have all the necessary monthly and yearly data for the observed building. Annual heating and cooling load were selected for a comparison of intended, actual and simulated building performance. Table 2.11 displays all the relevant values for the intended planning over a year which will be later reduced to 9 months.

Table 2.11: Annual heating - cooling - energy demand calculated with Archiphysik 8 (Baumgartner 2012)

	Reference climate		***Site climate***	
	Zone depended [$kWh \cdot a^{-1}$]	Specific [$kWh \cdot m^{-3} \cdot a^{-1}$]	Zone depended [$kWh \cdot a^{-1}$]	Specific [$kWh \cdot m^{-2} \cdot a^{-1}$]
HD*	197.899	6,83		
HD	612.789	80,41 $kWh \cdot m^{-2} \cdot a^{-1}$	836.106	**109,71**
HWH			194.723	25,55
CD*	4.771	0,16		
CD			118,233	**15,51**
HED			1.324.038	173,73
FED			1.330.156	174,53

HD* annual heating demand per conditioned gross volume

HD annual heating demand per conditioned gross area

HWH annual hot water heating per conditioned gross area

CD* annual cooling demand per conditioned gross volume

CD annual cooling demand per conditioned gross area

HED annual heating energy demand per conditioned gross area

FED annual (overall) final energy demand per conditioned gross area

2.9 **Building elements of the House B**

In architecture as well as in the medical sector, daylight plays a significant role in human health and comfort. Because of that, it is recommended to allow as much daylight in the rooms as possible without having large energy losses. Hence, windows and doors are important construction elements in terms of thermal behavior. Table 2.12 shows the thermal (U-Value) and energy transmittance (g) of the windows used for the hospital.

Table 2.12: Used U-Values and energy transmittance for windows in the EC calculation (Stugeba 2012)

Frame	Glazing	Heat insulation
high heat insulating steel reinforced frame	triple low energy glazing	g= 0.50
U_f= 1.00 W/m²K	U_g= 0.70 W/m²K	$U_{m,W}$ < 1.40 W/m²K

g	Energy transmission value
U_f	U-Value frame
U_g	U-Value glass
$U_{m,W}$	Insulation U-Value

Regulated by law, the building elements of the extension should not exceed the following heat transfer coefficients (U-Values) as shown in Table 2.13.

Table 2.13 and 2.14 present all building elements, which are far better than the recommended values of the OIB6. When the construction elements were assembled in the construction database of Tas, the building components had the same U-Values as in the EC. Only the values for windows and doors were different and had to be manipulated to adjust the Energy Certificate values.

Table 2.13: Construction elements with the U-Values according to the Austrian institute of construction engineering (OIB6: 2011)

Construction element according to OIB6	U-Value [W/m²K]
Floor to the ground	0,40
External Wall to the ground	0,40
External Wall	0,35
Internal wall between conditioned rooms	0,90
Internal wall between unconditioned rooms	0,35
Internal wall glass	2,50
Internal Floor/Ceiling	0,90
Flat roof	0,20
External wall technic room	0,60
Window	1,70
Door	1,70

Table 2.14: Construction elements U- Values modeled according to actual building construction in Tas Construction - Database

Construction element according to EC and Simulation database	U-Value [W/m²K]
Floor to the ground	0,17
External Wall to the ground	0,18
External Wall	0,21
Internal wall between conditioned rooms	0,30
Internal wall between unconditioned rooms	0,30
Internal wall glass	1,00
Internal Floor/Ceiling	0,10
Flat roof	0,12
External wall technic room	0,35
Window	1,00
Door	1,00

2.10 **Standards for simulation and Energy Certificate calculation**

Steady state and dynamic simulations rely on several standards for calculating the needed results. For dynamic simulation it is important to know in which norm different aspects as internal gains, thermal environment, insulation and other important factors can be found. In Austria, for the steady state and dynamic simulations the ÖNORM B (Building Industry), H (Building Services) and the OIB6 (Energy economy and heat retention) are primarily used (Battisti and Somogyváry 2010). Table 2.15 gives the standards, which were used for the simulation scenarios in this thesis.

Table 2.15: Used standards for defining the simulations parameters (Austrian Standards Plus 2013)

ÖNORM B 8110-5:2011	Thermal insulation in building construction: Model of climate and user profiles
ÖNORM B 8110-6:2011	Thermal insulation in building construction: Heating and cooling demand
ÖNORM EN 15251:2007	Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
ÖNORM EN 12464-1:2011	Light and lighting – Light of work places Part 1: Indoor work
ÖNORM EN ISO 13790:2008	Energy performance of buildings – Calculation of energy use for space heating and cooling
OIB 6:2011	Energy economy and heat retention

2.11 **EDSL Tas simulation software**

The used software EDSL Tas Version 9.2.1.4 (Thermal analyses software) is a package of application products, which simulate the dynamic thermal performance of buildings and their systems. The main module is Tas Building Designer, which performs dynamic building simulation with integrated natural and forced airflow. It has a 3D graphics-based geometry input that includes a CAD link for a faster workflow. Furthermore zones are assigned to the modeled spaces according to their conditions. The software combines dynamic thermal simulation of the building structure with natural ventilation calculations, which include advanced control functions on aperture opening and the ability to simulate complex mixed mode systems (Crawley et al. 2008). In the Building Simulator all data regarding the materials and materials properties of construction elements is considered. Important parameters as weather conditions, internal conditions and schedules for heating and cooling can also be manipulated here. After running the simulation, the Result Viewer provides the user with concise results and graphs of the overall performance of the simulated building. Tas has more than 20 years of commercial use around the world.

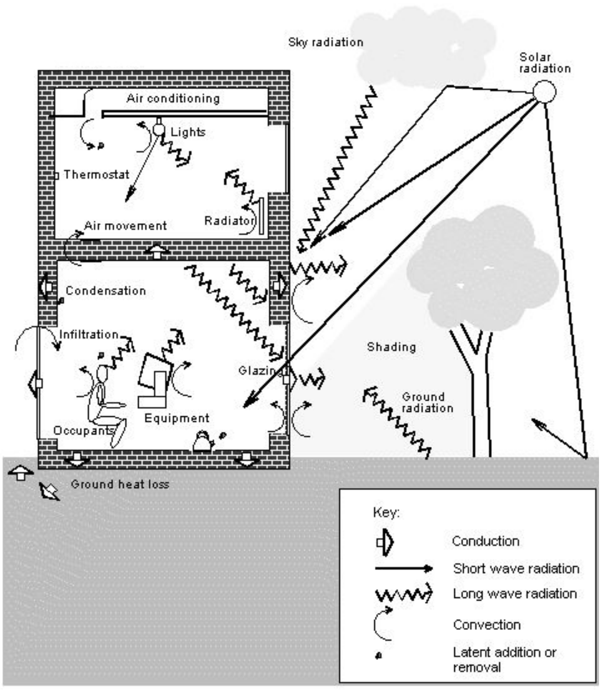

Figure 2.23: Representation of heat transfer in a building (EDSL 2013)

2.12 **Zoning in Tas**

Tas provides the user with the possibility of defining spaces in building models as zones. A zone is a delimited area within the building in which air temperature and humidity are assumed to be uniform. Different zones are usually assigned to spaces that have different properties, or if it is necessary to make a separate analyses for whatever reason. Zoning allows the user to adjust internal conditions by modifying ventilation rate, infiltration rate, occupancy sensible load, equipment gains, light gains, and thermostat. Furthermore, each zone is part of the building and indirectly linked to neighboring zones through connected surfaces objects.

Figure 2.24 displays the zoning of the ground floor, where each color shows the different areas. When determining the zones it is necessary to take into consideration not only the differences in temperature and humidity, but also the orientation of the building and its complexity, so that when doing the simulation there are enough zones for an accurate evaluation.

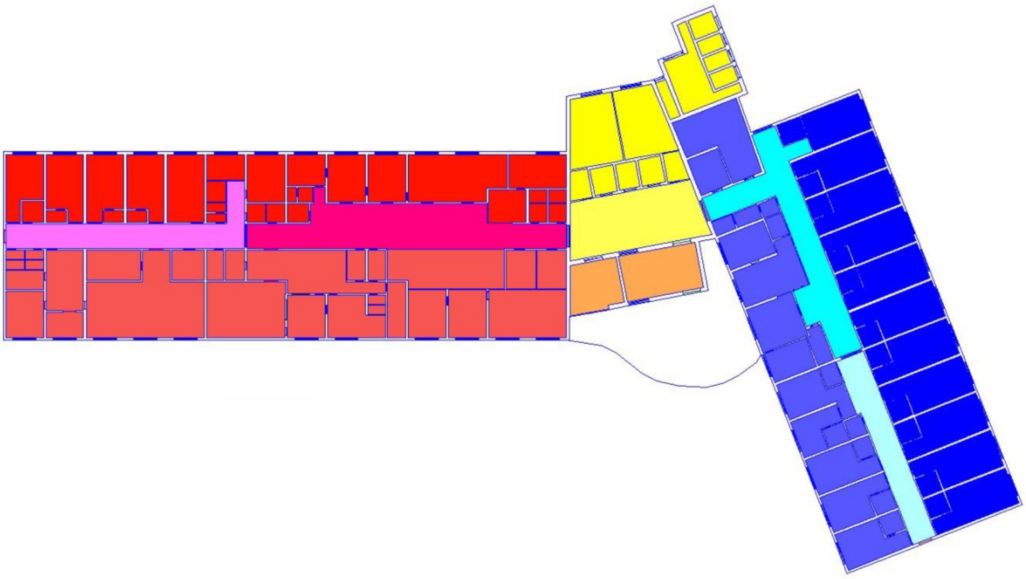

Figure 2.24: Zoning of the ground floor of the House B assigned in Tas

Table 2.16: Zones with according net area and net volume of the House B generated by Tas

Floor	Zone Name	Zone Nr.	m²	m³
Ground Floor	IMCU North	1	306,85	1086,23
	ICU + Angio South	2	456,88	1617,34
	OPW Corridor1	3	67,16	237,74
	OPW Corridor2	4	116,92	413,91
	Technic Room	5	139,3	497,51
	Middle Corridor	6	75,78	268,174
	Entrance + Staircase	7	60,09	221,65
	Inpatient Ward East	8	347,86	1231,42
	Inpatient Ward West	9	271,69	961,77
	IPW Corridor1	10	89,89	318,2
	IPW Corridor2	11	51,82	183,44
1st Floor	Inpatient Ward North	12	252,89	831,99
	Inpatient Ward South	13	446,74	1469,76
	IPW Corridor1	14	69,79	229,62
	IPW Corridor2	15	76,01	250,06
	Technic Room	16	144,45	486,69
	Middle Corridor	17	100,85	331,79
	Staircase	18	35,72	140,73
	Inpatient Ward East	19	347,86	1144,46
	Inpatient Ward West	20	271,56	893,44
	IPW Corridor3	21	89,89	295,73
	IPW Corridor4	22	51,82	170,49
2nd Floor	OP South	23	201,34	662,4
	Prep + Recovery South	24	298,6	982,38
	Preparation North	25	186,96	615,11
	OPW Corridor1	26	89,66	294,97
	OPW Corridor2	27	67,39	221,71
	OPW Corridor3	28	27,65	90,98
	Technic Room	29	94,32	321,77
	Middle Corridor	30	100,85	331,79
	Staircase	31	35,72	140,73
	Inpatient Ward East	32	351,65	1156,92
	Inpatient Ward West	33	270,04	888,47
	IPW Corridor1	34	86,15	283,47
	IPW Corridor2	35	53,47	175,91
3rd Floor	Building Services	36	502,19	1652,21
	Locker Room North	37	75,48	248,32
	Locker Room South	38	108,74	357,75
	Technic Corridor	39	19,9	65,46
	Corridor Middle	40	75,88	249,65
	Staircase	41	58,83	207,83
	Inpatient Ward East	42	351,65	1156,92
	Inpatient Ward West	43	270,94	891,39
	IPW Corridor1	44	86,46	284,44
	IPW Corridor2	45	51,88	170,68
	Technic Room	46	28,45	100,64
	Net Area/ Net Volume		**7366,02**	**24834,04**

2.13 **Internal conditions calculations**

The internal conditions represent important calculation parameters for simulation programs, which can have significant effects on the results. For the simulation's internal loads the input data should include the convective and radiative portion of heat flow from lighting, people and internal equipment in Watts per unit floor area. The convective portion of the energy emanating from the internal sources affects the air temperature instantly. The absorbed energy from the building structure and furniture contributes to the space heating or cooling load after a certain time. On the one hand the fresh air infiltration (leakage) into the zones expressed in air changes per hour (ach) has the greatest influence in the heating and cooling demand. On the other hand, the fresh air which enters the zones via a mechanical ventilation system makes it possible to obtain an estimate of the total load without the analysis of a detailed air conditioning system (EDSL 2013).
Necessary internal gains for the simulated actual and intended scenario were chosen and calculated according to the standards mentioned above (Table 2.15).

The thermostat in Tas controls the temperature and humidity for the simulation and contains a value table with the following four parameters:

- The upper limit of the cooling control band
- The lower limit of the heating control band
- Humidity upper limit to set the maximum acceptable zone humidity
- Humidity lower limit to set the minimum acceptable zone humidity

For the Energy Certificate simulation, many data sets as air change rate and internal gains for unconditioned zones have to be excluded, because these data are neither considered in the Energy Certificate nor can be set manually.

The internal gains and the air change rate are taken as one value in the EC, whereas in Tas these values are divided in sub categories, which will be explained in the following pages.

Table 2.17: Parameters used for the EC, Scenario1, Scenario 2 and Scenario 3 simulations (Austrian Standards Plus 2013)

	Unit	EC	S1 and S2	S3
Θ_{ih}	*°C*	20	22	20
Θ_{ic}	*°C*	20	26	20
$n_{L\ con}$	*1/h*	2	2	2
$n_{L\ uncon}$	*1/h*	excluded	0,5	excluded
$q_{i,h,n}$	*W/m²*	7,5	zone depended	7,5
$q_{i,h,n\ uncon}$	*W/m²*	excluded	1	excluded
E_m	*lx*	excluded	200-1000	excluded

Θ_{ih}	set-point temperature of conditioned zone (heating)
Θ_{ic}	set-point temperature of conditioned zone (cooling)
$n_{L\ con}$	air change rate
$n_{L\ uncon}$	air change rate for unconditioned zone
$q_{i,h,n}$	internal gains (people, equipment, lighting)
$q_{i,h,n\ uncon}$	internal gains for unconditioned zone
E_m	maintained luminance

2.14 **Data for actual performance simulation (S1 and S2)**

The dynamic simulation of the actual demand is a more sophisticated and time consuming method as the steady state calculation of the Energy Certificate.
In the 3D-Modeler the building was designed as accurate as possible with all its floor levels, openings and windows, doors, building elements, zones and site location parameters. For the actual loads, two simulation scenarios, one according to the Austrian standards (S1) and one proposed with calculated internal gains and air change rate (S2) were conducted. The building's shades were not considered in none of the simulation scenarios because of the individual use which was not monitored and could not be depicted.

After the model was set up in the 3D-Modeler, the model information was exported into the Building-Simulator for further processing. In the Building-Simulator a calendar was set for weekdays and weekends. Also schedules were used for the second scenario with proposed parameters.

The used weather file for Wiener Neustadt was provided by the ZAMG and modified for the simulation software. The building elements are the same as for the EC, both taken from the construction plan of the company STUGEBA. The U-Values of the building elements can be seen in Table 2.15. The zoning for the actual simulation scenario (S1) according to the standards has on each floor an individual arrangement with varying internal condition as shown in the following Table 2.18.

The infiltration and ventilation ach values also differ for each ward as the lighting, occupancy and equipment gains do. The thermostat´s lower and upper temperature limits were set to 22 to 26 °C as described in the ÖNORM EN 15251. The needed room luminance given in lx for hospitals was taken from the regulated standard ÖNORM EN 12464-1. Occupancy, equipment and lighting gains were simulated with parameters from ÖNORM EN ISO 13790.

Tas performs a dynamic simulation and therefore requires a starting point for its analysis. The starting point assumed in Tas is a steady state condition corresponding to an inside air temperature of 18°C in all zones and an outside air temperature set to the value read from the weather file for the first hour of the simulation. Only after a certain time the effects of these starting assumptions become negligible, so it is advisable to start the simulation a few days in advance of the date when the first output is required. The extra simulation days constitute the preconditioning period. A 15 days preconditioning time as recommended in the Tas manual was used for all simulation scenarios (EDSL 2013).

Using all these data the simulation for scenario one, considering the standards was run to get the heating and cooling profile in watts for nine months. With an excel tool provided by the department of Building Physics at the Vienna University of Technology, the results were copied from the results viewer of Tas and pasted into the excel tool for calculating the heating and cooling demand of the hospital.

Table 2.18: Internal conditions for the zones in House B for the actual demand simulation according to the standards (Scenario 1) [Austrian Standards Plus 2013]

Internal Gains (S1)	Units	IW	BS	OW	OP	SC
Infiltration	ach	1	1	1	1	1
Ventilation	ach	1	1	1	1	1
Lighting Gain	W/m²	2,5	1	2,5	2,5	2,5
Occupancy Sensible Gain	W/m²	2,5	1	2,5	2,5	1
Equipment Sensible Gain	W/m²	2,5	2,5	2,5	2,5	0
Thermostat upper Limit	°C	26	26	26	26	26
Thermostat lower limit	°C	22	22	22	22	22
Humidity Upper Limit	%	70	70	60	60	70
Humidity Lower Limit	%	40	40	40	40	40
Target Room Illuminance	lx	300	200	500	1000	200

IW = Inpatient Ward, BS = Building Services rooms, OW = Outpatient Ward,
OP = Operating Theaters, SC = Staircases

For the second scenario (S2) of the actual demand simulation, all the used values were chosen from real performance data of the hospital combined with the ÖNORM EN ISO 13790 and ÖNORM EN 15251.

Schedules for Inpatient Ward, Building Services rooms, Outpatient Ward, Operating Theaters and Staircase were implemented in the simulation, concerning the working hours and occupancy level during day and night. Each day the internal gains varied in lighting, occupancy and equipment gains. Different activity levels of people emit different amounts of watts, which were calculated per square meters with the daily amount of occupants in the hospital. This was also performed for the equipment used in the extension.

The following equipment was chosen in order to get the appropriate data for the simulation assumptions (S2).

- Desktop PC has a power demand of 65W. This is the average value for desktop power given by CIBSE Guide A. (CIBSE 2006)
- Monitor is selected as 22”, with average power consumption of 36W (from commercially available models as they are used in the hospital)
- A flat screen TV with 42” has a power demand of 80W as used in the hospital (Roberson et al. 2004)
- A laser printer has a demand of 130W (Wilkins and Hosni 2000)
- A large copy machine has a demand of 800W (Wilkins and Hosni 2000)

Table 2.19 presents the equipment used in the extension building for each floor and ward. For the angiography room, the C-arm X-ray machine (Figure 2.13) is calculated with a power value of 80 kW (Kalender 2006). For the operating theater the values were given by the hospital’s building technician. Each operation room is equipped with eight monitors as shown in Figure 2.12. The night time shutdown was considered for all devices in the calculation of the equipment internal gains as shown in Table 2.20.

Table 2.19: Equipment per floor in the Outpatient and Inpatient Ward (Stugeba 2012)

OUTPW	TV	PC	Printer	Copier
GF	2	21	9	1
1st	15	5	3	0
2nd	1	0	0	0
3rd	0	0	0	0
INPW				
GF	15	5	3	0
1st	15	5	3	0
2nd	15	5	3	0
3rd	15	5	3	0

Table 2.20: Devices power and shutdown values (Roberson et al. 2004)

Device Category	Power (W)		Night-time shutdown	Device
	On	Off		
Desktop	65	2	60%	Intel Core i7 Duo
Monitor	36,5	0,5	80%	BenQ 22"
Flat screen TV	80	1,5	100%	Samsung 42"
Laser Printer	130	10	100%	Typical small office type
Copy Machine	800	300	100%	Large Size, Multi-User

For the occupancy internal gains the hospital is assumed to be occupied every day. For simplicity, weekends are assumed to be less occupied and public holidays as well. Standard values are given in ÖNORM EN 12464-1 and are 75W for sensible heat respectively, whereas the latent heat was not considered for the simulation (Table 2.21). These values are multiplied with occupancy utilization rates and workstation density to calculate heat gain per m².

Table 2.21: Heat generation by people for different activities (Dry Bulb Temperature 24°C) [ÖNORM EN 12464-1: 2011]

Activity	Total heat		Sensible Heat
	Met	**W*Person$^{-1(a)}$**	**W*Person^{-1}**
Reclining	0,8	80	55
Seated relaxed	1	100	70
Sedentary activities	1,2	125	75
Standing, light activity	1,6	170	85
Standing, moderate activity	2	210	105
Walking, 5km/h	3,4	360	120
(a) approximated values			

The metabolic rate, or human body heat production, is often measured in the unit "Met". The metabolic rate of a relaxed seated person is about 1 Met, where 1Met is 58 W*m^{-2}. The total metabolic heat for a mean body can be calculated by multiplying it with the surface area, which is approximately 1,8m² for an adult. Therefore, the total heat from a relaxed seated person with mean surface area would be 100W.

Lighting simulation is a complex process. Standard values from the ÖNORM EN 15251 and 12464-1 were used to simulate the internal sensible loads. Lux values for different working areas with special requirements as presented in Table 2.22.

Table 2.22: Lux disclosures for different rooms in the health care sector (ÖNORM EN 15251:2007)

Interior spaces	lx
Corridor	200
Lounge	200
Office	500
Nurse station	500
Inpatient Ward	300
Outpatient Ward	500
Sanitary facilities	200
ICU	500
Operating Theater	1000
Technic	300

The presented values in Table 2.23 were used for the proposed scenario simulation (S2) in Tas.

Table 2.23: Purposed calculated internal conditions for zones in House B for the actual demand simulation Scenario 2 (ÖNORM EN 15251:2007; ÖNORM EN 12464-1: 2011)

Internal Gains (S2)	Units	IW	BS	OW	OP	SC
Infiltration	ach	0,5	0,5	0,5	1	0,5
Ventilation	ach	0,5	0,5	0,5	1	0,5
Lighting Gain	W/m²	2,5	1	2,5	2	2,5
Occupancy Sensible Gain	W/m²	5,6	1	5,2	2,7	1
Equipment Sensible Gain	W/m²	8	20	8	8	0
Thermostat upper Limit	°C	24	24	24	22	24
Thermostat lower limit	°C	22	22	22	22	22
Humidity Upper Limit	%	70	70	60	60	70
Humidity Lower Limit	%	40	40	40	40	40
Target Room luminance	lx	300	200	500	1000	200

The simulation's schedules were set for each ward differently as shown in Table 2.24. Schedules, which are time series of 0's and 1's, one value for each hour of the day, are used to specify when a gain is using its value or setback value.

Table 2.24: Schedules for working and non-working hours in different zones of the hospital Scenario 2

Hour	Inpatient ward	Outpatient ward	OP	Technic rooms	Staircase
1	0	0	1	0	0
2	0	0	1	0	0
3	0	0	1	0	0
4	0	0	1	0	0
5	0	0	1	0	0
6	1	1	1	1	1
7	1	1	1	1	1
8	1	1	1	1	1
9	1	1	1	1	1
10	1	1	1	1	1
11	1	1	1	1	1
12	1	1	1	1	1
13	1	1	1	1	1
14	1	1	1	1	1
15	1	1	1	1	1
16	1	0	1	1	1
17	1	0	1	1	1
18	1	0	1	1	1
19	1	0	1	0	1
20	1	0	1	0	1
21	1	0	1	0	1
22	1	0	1	0	1
23	0	0	1	0	0
24	0	0	1	0	0

2.15 **Data for the Energy Certificate simulation (S3)**

For the simulation of S3 it is important to carefully choose the right parameters from the Energy Certificate and standards to be able to make a precise analysis of the simulated EC in Tas afterwards. For the third scenario the same values as for the Energy Certificate were selected.

For hospitals, the ÖNORM B 8110 – 5 prescribes an air change rate of 2 h^{-1}, but for the simulation, infiltration and ventilation were split into 1 ach each.
Heat gains, emitted by equipment, lighting and the metabolic processes of occupants were taken into account with a sensible gain set to the flat rate value of 7,5 W/m² as defined by Austrian standards for hospitals. For the thermostats upper and lower limit the same value of 20°C as the one from the EC was chosen, having in mind that Archiphysik starts heating up a zone, when the outside temperature drops under 12°C, whereas in the simulation, energy is used when the inside temperature is under 20°C.

Table 2.25: Internal conditions for the zones in House B for the intended demand simulation (S3) [Baumgartner 2012]

Internal Gains (S3)	**Values**	**Units**
Infiltration	1	ach
Ventilation	1	ach
Lighting Gain	2,5	W/m²
Occupancy Sensible Gain	2,5	W/m²
Equipment Sensible Gain	2,5	W/m²
Thermostat upper Limit	20	°C
Thermostat lower limit	20	°C
Humidity Upper Limit	x	%
Humidity Lower Limit	x	%
Target Room luminance	x	lx

In Archiphysik the zoning is divided into conditioned and unconditioned zones. The user does not have the same freedom to create zones with different internal conditions as in Tas. For the Energy Certificate simulation all the building zones were assumed as conditioned with the same internal gains.

The used weather file is the one provided by the ZAMG and not the one from Archiphysik.

The hospital’s extension model, built up in Tas 3D-Building Modeler was for all simulations scenarios the same.

3 RESULTS AND DISCUSSION

This chapter presents the results of the method outlined in the previous one. Chapter sections include the research questions that were posed in the introduction and the results of the simulated building performance for the case study of MCWN’s extension. The first and second scenario consist of two simulations of the actual heating/cooling loads, one according to the standards for hospitals and the other based on proposed parameters. The third one deals with the simulation of intended performance by using the same parameters as in the Energy Certificate. The outcomes are illustrated below in graphs with captions and additional explanations. In all three cases the monthly actual heating/cooling demands were considered as relative reference values of 100%.

3.1 Analysis of monitored actual demand results

The hospital’s extension is monitored since commissioning date by the company Ingsoft with the software Interwatt for a better energy performance insight. Heating and cooling systems are connected to main and sub meters to count the needed energy for cooling and heating purposes as described in the methods.

The ventilation system is used for both, cooling and heating the hospital and comprises of multiple modules as illustrated in Table 3.1. Additional systems as cooling ceiling, air cooler and an air curtain, radiators and under floor heating (UFH) support the air conditioning system as described in detail in the HVAC description of the House B.

Table 3.1: Range of ventilation system modules for heating and cooling (Zentraplan 2012)

Module	Range of ventilation system
L01	Ventilation system for fresh air/exhaust air OP 1-4
L02	Ventilation system for circulation air OP 1-4
L03	Ventilation system for adjacent OP rooms
L04	Ventilation system for Outpatient ward and Angiography
L05	Ventilation system for Inpatient ward and IMCU
L06	Ventilation system for Locker rooms
L07	Ventilation system for Inpatient ward east and staircase

Table 3.2 presents the amount of MWh per month for the cooling system modules. The combined ventilation system L01-L02 providing the Operation Rooms with fresh air had the highest value for cooling, especially in the hotter months. That is because all four Operating Theaters had to be at all times ready for emergency surgeries. The cooling demand of L01-L02 doubled from October to June from 10,05MWh to almost 19,82MWh, because warmer air had to be cooled down to standard temperatures of 22°C to 26°C. The recirculation air cooler, with a total amount of 79,92MWh rose from 5,40MWh to 11,70MWh with the increasing of outside temperatures. Compared to the other ventilation systems, L04's energy consumption rose from 2,50MWh in October to 23,63MWh in June (89,42%).

Table 3.2: Actual cooling demand from October 2011 until June 2012 in MWh (Interwatt 2012)

Cooling (MWh)	Cooling ceiling	Air cooler	L01+L02	L03	L04	L05	L06	L07
Oct	0,00	5,40	10,05	1,03	2,50	2,11	0,17	0,13
Nov	1,78	8,28	9,57	0,33	0,13	4,21	0,00	0,00
Dec	3,14	8,93	6,95	0,06	0,00	6,43	0,00	0,00
Jan	3,31	8,84	3,27	0,48	0,00	6,59	0,00	0,09
Feb	1,60	8,27	4,69	0,73	0,00	1,87	0,00	0,34
Mar	2,71	8,74	7,81	1,35	0,29	2,69	0,04	0,13
Apr	2,71	9,02	8,77	1,40	1,57	2,83	0,30	0,97
May	2,33	10,74	13,89	2,75	10,03	3,26	0,74	2,79
Jun	2,09	11,70	19,82	11,03	23,63	7,21	1,69	16,41
Sum	**19,68**	**79,92**	**84,82**	**19,16**	**38,15**	**37,20**	**2,93**	**20,86**

Based on Figure 3.1, the monitored actual cooling demand for each month can be seen according to the combination of the different cooling systems in MWh. Furthermore the graph shows why the cooling demand also in the winter months was very high. It is apparent that many adjustment configurations were done in the first months, because the cooling ceiling e.g. was activated for the first time in November, which explains the lower demand in October. Although most of the hospital area is dedicated to the Inpatient ward, the cooling load was lower than the one for the operating rooms, which implies the importance of those rooms. The air cooler was constantly running with a demand of 8,28MWh to 11,70MWh, except October. In June a significant high cooling demand arose from the Outpatient ward, with a significant output of over 90MWh per month. It would be interesting to observe the other summer months, July and August, to see how far the MWh/Month bar could rise.

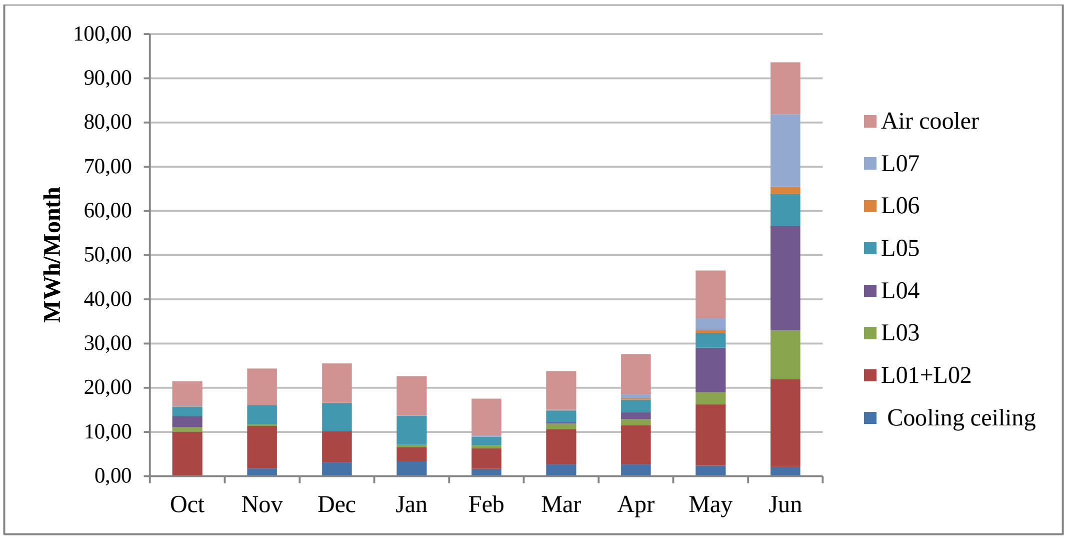

Figure 3.1: Actual cooling demand module combination per month in MWh for House B (Interwatt 2012)

In order to heat the hospital much more energy was used to fulfill the hospital's requirements. By observing the energy demand of the radiators and the under floor heating it is obvious that the amount of 270,41MWh for nine month is higher than the ventilation's heating systems. Although in May and June the radiators were rarely used, the heating demand from the air conditioning system was still notable with 18,30MWh in May and even higher in June (23,57MWh). This is because of the special humidity requirements for hospitals, where the supplied air has to be cooled down to dehumidify and then again heated up to reach the required temperature, especially for the Outpatient ward and the Operation Theater's adjacent rooms.

Table 3.3: Actual heating demand from October 2011 until June 2012 in MWh (Interwatt 2012)

Heating (MWh)	Air curtain	Radiator/ UFH	L02+L01	L03	L04	L05	L06	L07
Oct	1,92	25,89	2,66	2,83	7,52	1,91	0,00	4,48
Nov	1,32	48,59	4,76	5,94	10,37	9,26	0,00	7,71
Dec	1,27	45,81	4,68	5,59	9,51	12,98	0,00	9,49
Jan	1,30	49,94	2,71	6,90	10,22	13,95	0,00	10,16
Feb	1,28	52,87	3,57	15,45	17,49	12,82	0,17	14,34
Mar	1,00	25,97	0,44	3,87	5,82	8,69	0,48	4,61
Apr	0,58	19,51	0,32	2,41	5,44	7,11	0,51	3,34
May	0,50	1,83	0,60	1,53	9,60	3,44	0,37	0,43
Jun	0,46	0,00	1,42	5,36	15,16	0,86	0,00	0,31
Sum	**9,63**	**270,41**	**21,17**	**49,88**	**91,12**	**71,02**	**1,53**	**54,88**

As shown in Figure 3.2, the heating demand had its peak load of 117,96MWh in February, which occurred on one side because of the radiators and under floor heating and also because of the warm air supply through L04 in the Outpatient ward and L05 + L07 in the Inpatient ward. Furthermore the ventilation system needed almost half of the composed energy demand with the UFH and radiator system. In June, precisely 50% less energy was used for heating up the supplied air compared to October. Because of such complex code requirements for heating and cooling systems in the health care system, it is important to monitor the building to see how much energy is used for the actual energy performance. For analyzing the actual demand in detail, the different simulation scenarios were run.

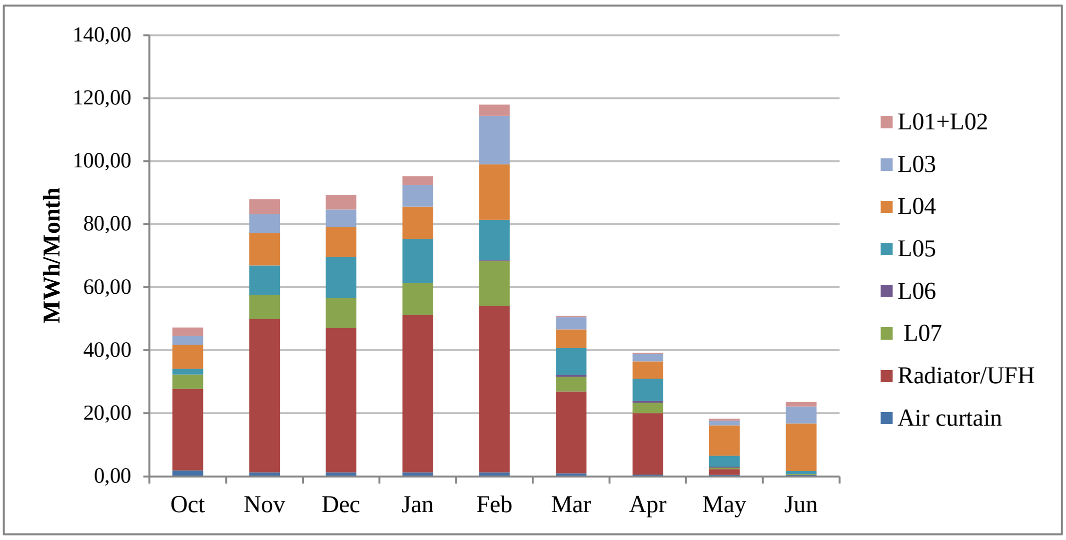

Figure 3.2: Actual heating demand module combination per month in MWh of House B (Interwatt 2012)

3.2 Comparison of actual demand between S1 and S2

Figures 3.3 and 3.4 analyze the actual demand with the simulated Scenario 1 (S1) and Scenario 2 (S2). The differences between the two scenarios are illustrated in percentage in Table 3.4 and 3.5.

Scenario 1 is the simulation of the real demand, considering the Austrian standards. The monthly S1 results show a higher heating demand as the actual one, because of standard parameters like air change rate and internal gains, which are not as accurate as they should be. Firstly, the infiltration and ventilation are considered as one value in the standard. For the simulation the value was split into 1ach for infiltration and 1ach for ventilation. Housez (2011) suggested in his research about comparative methods for assessment of buildings heating demand due to thermal refurbishment, that the ventilation and infiltration values have the biggest effect in heating and cooling loads. The second cause for the higher demand was the internal gains which were set all the same for the entire period.

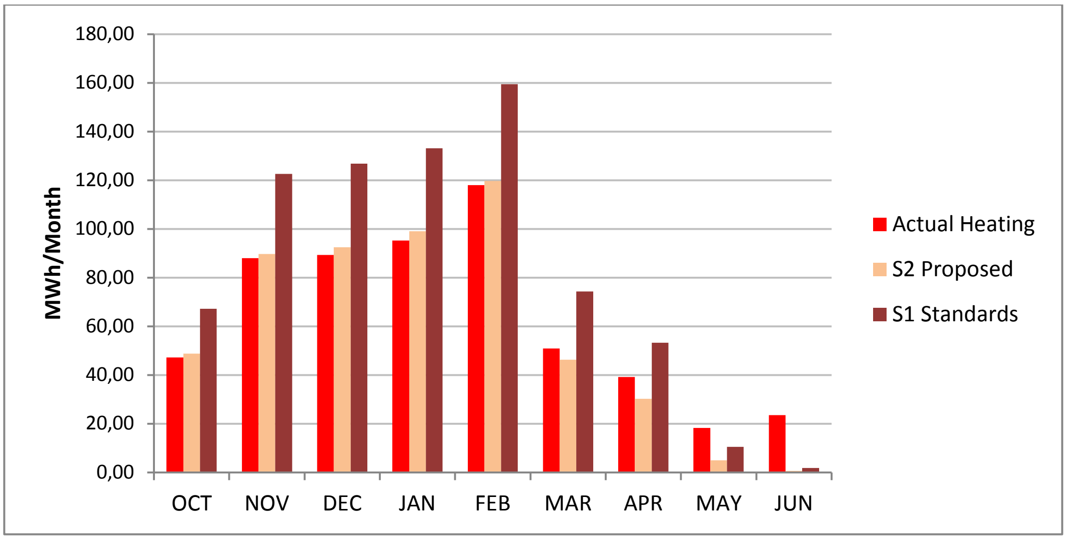

Figure 3.3: Actual heating demand in comparison to Scenario 1 and Scenario 2

Scenario 2 considered the real temperature data which had to be provided in a hospital and all the necessary internal gains values in real time in accordance with the schedules. Also the infiltration and ventilation values were taken as the actual ones with 0,5 ach each. Because of that, the S2 results are more accurate than the S1 outcomes.

Table 3.4 shows that the S2 differences for the monthly simulated heating demands were from October till February not higher than 5% in comparison to the actual load. From April until June the S2 simulated loads substantially decreased to almost 1MWh, which could be traced back to the unconsidered ventilation's system in Tas during the summer months. All in all the proposed simulation was very close to the actual demand from October until March, whereas Scenario 1 was always to high except the summer months.

Table 3.4: Differences between S1 and S2 in contrast to the actual heating demand in percent

Month	AH – SIM AHSt Scenario 1	AH – SIM AHPr Scenario 2	SIM AHSt – SIM AHPr S1 – S2
OCT	-42,5%	-3,5%	27,4%
NOV	-39,3%	-2,0%	26,8%
DEC	-41,9%	-3,6%	27,0%
JAN	-39,9%	-4,0%	25,7%
FEB	-35,1%	-1,4%	24,9%
MAR	-46,0%	9,0%	37,7%
APR	-35,8%	22,7%	43,1%
MAY	42,3%	72,6%	52,6%
JUN	92,2%	97,3%	65,7%

It is obvious that the simulation was not able to predict the cooling load as accurate as the heating load, neither for S1 nor S2. Figure 3.4 shows that for the standard simulated Scenario 1, energy was consumed for cooling only in the last three months. This is because the simulation did not consider the extension's ventilation system in the cold months. The much higher actual cooling demand shows the consumed energy in reality.

Scenario 2 is also far from the actual cooling load, but still cooled in more months than the S1 simulation. This occurred because the calculated internal gains were much higher than the standard ones, which lead to higher inside temperatures and therefore Tas performed cooling. The actual energy demand during the summer months was caused because of the outside air which had to be mechanically lowered to reach the standard humidification and temperatures for hospitals. The actual set point settings of the ventilation system in the hospital were responsible for the higher cooling demands.

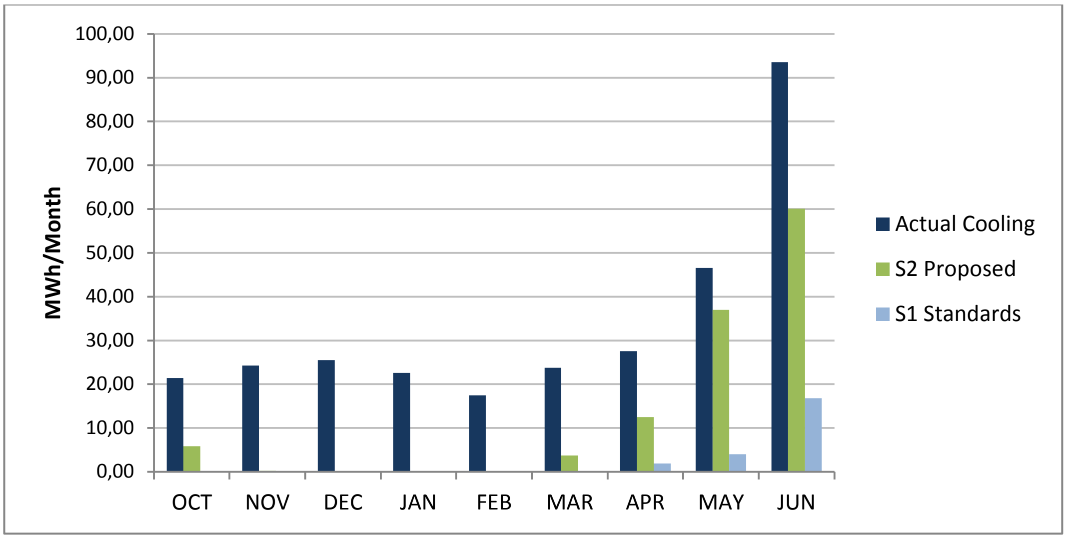

Figure 3.4: Actual cooling demand in comparison to Scenario 1 and Scenario 2

Table 3.5 presents the percentage of the differences between the actual cooling demand and scenarios S1 and S2 in detail. It is apparent that none of the simulated scenarios was close to the actual cooling demand. The continuous loads arose from the ventilation system, because the heated zones had to be cooled down by the cooling ceiling. In fact, more than half of the time S1 was not cooling, whereas S2 was performing better but still could not come close to the actual cooling load. In May the S2 simulation had the lowest difference of 20,5% .

Table 3.5: Differences between S1 and S2 in contrast to the actual cooling demand in percent

Month	AC - SIM ACSt Scenario 1	AC - SIM ACPr Scenario 2	SIM ACPr - SIM ACSt S1 – S2
OCT	99,9%	72,6%	99,5%
NOV	100,0%	99,0%	100,0%
DEC	100,0%	99,9%	100,0%
JAN	100,0%	100,0%	100,0%
FEB	100,0%	99,3%	100,0%
MAR	100,0%	84,4%	99,8%
APR	93,2%	54,8%	85,0%
MAY	91,4%	20,5%	89,2%
JUN	82,0%	35,8%	72,0%

3.3 Comparison between actual demand and S3

Within Scenario 3 (S3) the actual demand is compared with the intended demand of the Energy Certificate. The internal conditions were chosen according to the EC, whereas the weather file was the same as in S1 and S2. Because the EC had a different weather file, the purpose of this simulation was to determine, how big the differences would be by using a more detailed local climate file (ZAMG).

In Figure 3.5 the columns present the actual, intended (EC) and simulated intended heating (S3) demand. Both, simulated EC and intended demands were higher than the actual one. That is because of the simplified air change rate and internal conditions, which were too high set. Furthermore the heating design days of the EC's weather file were about 5% higher than the Simulation's weather data, thus also influencing the results.

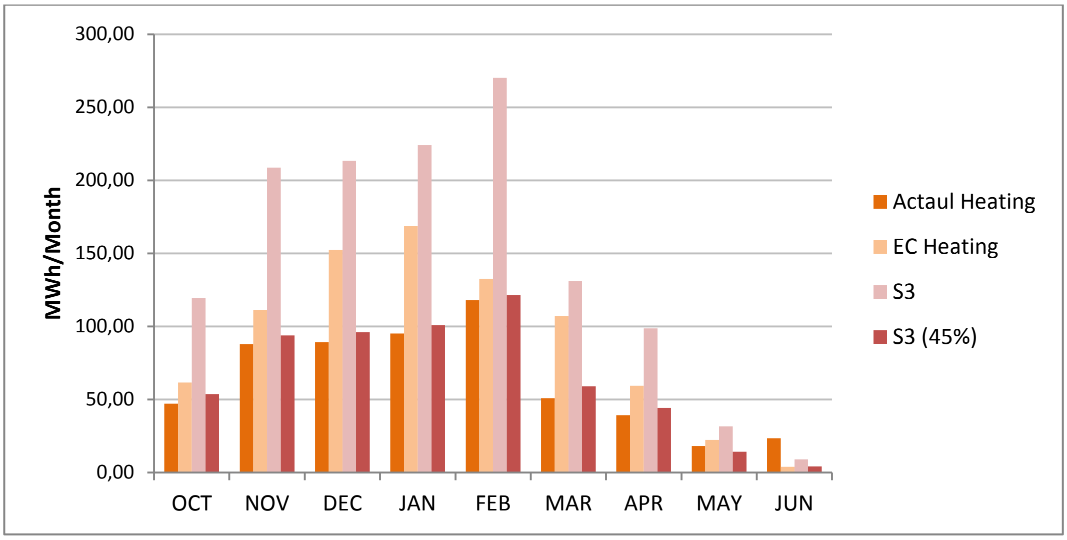

Figure 3.5: Actual heating demand in comparison to Scenario 3 and S3 lowered by 45%

The higher EC demands rose because of the gathered ventilation and infiltration value of 2 ach. It is apparent, when looking at the simulated EC demands (S3) that they were much higher than the EC's monthly demands.

This indicates that the chosen standard values influence the dynamic simulation more than the EC calculation.

Neither the intended nor the simulated intended values considered in this case the actual ventilation system, which would cause in reality an oversized heating system, because of the enormous loads.

As mentioned in the HVAC description, the actual air conditioning system is capable of saving up to 40% – 60% energy by the cross flow heat exchanger (Friedl 2011). Hence the Tas results were lowered by 45%, to consider the energy saving of the system (S3 lowered by 45%). By doing that, also the simulated results according to the EC values dropped close to the actual heating demand, which proves that the standard values have to take the energy savings into account when complex buildings are involved. But a lowering by 45% of the EC demand cannot derive approximate values for the actual loads. Hence, the outcomes would be too low and therefore would lead to an undersized heating system.

In Table 3.6 the differences between actual, EC, S3 and S3 lowered by 45% demands are presented in percentage. From the comparison of the actual and intended heating demand, the smallest difference of 12,4% was achieved in February and the highest one in March with a mismatch of 110,7%. The outcomes of the simulated intended energy consumption (S3) had the lowest value of 72% in May. The highest difference from the actual one was in March (157,4%). Considering the differences between actual and S3 lowered by 45% demands, the results were close to the actual one with only 3% difference in February and the highest one in March (15,8%).

Table 3.6: Differences between S3 and S3 lowered by 45% demands in contrast to the actual heating demand in percent

Month	AH – EC Heating	AH – S3	AH – S3 (45%)	EC Heating - S3 (45%)
OCT	-30,7%	-153,3%	-14,0%	12,76%
NOV	-26,6%	-137,3%	-6,8%	15,62%
DEC	-70,5%	-138,9%	-7,5%	36,94%
JAN	-77,1%	-135,5%	-6,0%	40,17%
FEB	-12,4%	-128,9%	-3,0%	8,32%
MAR	-110,7%	-157,4%	-15,8%	45,02%
APR	-51,4%	-151,3%	-13,1%	25,33%
MAY	-22,0%	-72,2%	22,5%	36,44%
JUN	83,0%	61,5%	82,7%	-2,02%

Although in most of the months neither the EC nor the simulation were cooling at all times, the simulated values were higher than the intended ones. But lowering the Tas results by 45% as it was done for the heating demand, the values came closer to the EC ones. This means that the lowering of the simulated demand in this particular case would not help in getting closer to the actual cooling demand.

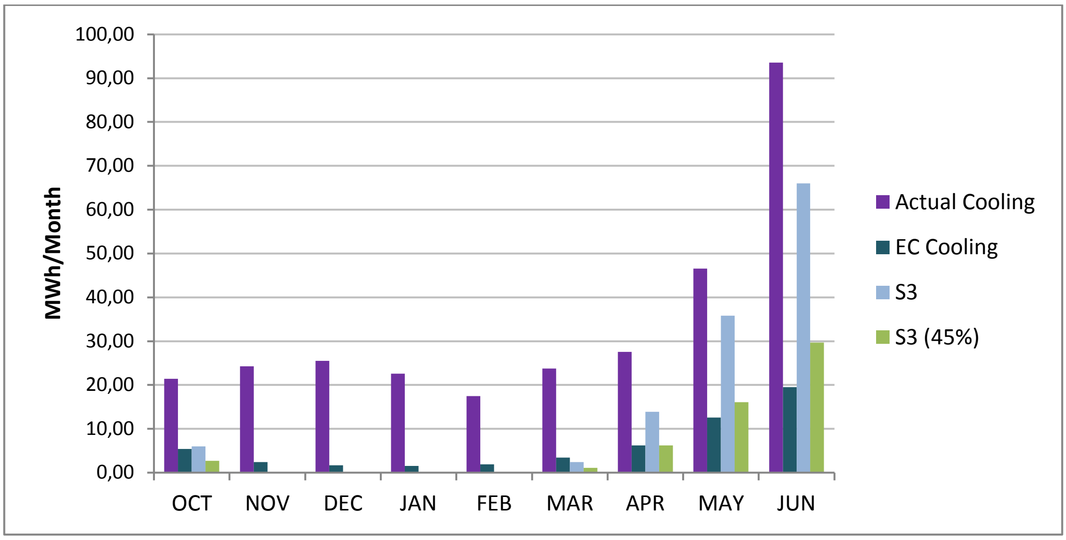

Figure 3.6: Actual cooling demand in comparison to Scenario 3 and S3 lowered by 45%

Table 3.7 shows that in most of the months the values differed by 100%. Only the differences of the lowered simulation results with the intended ones in April and May were close to each other, which were still too low in contrast to the actual cooling loads.

Table 3.7: Differences between S3 and S3 lowered by 45% in contrast to the actual cooling demand in percent

Month	AC – EC Cooling	AC – S3	AC – S3 (45%)	EC Cooling – S3 (45%)
OCT	74,6%	72,0%	87,4%	50,6%
NOV	89,9%	100,0%	100,0%	99,9%
DEC	93,5%	100,0%	100,0%	100,0%
JAN	93,3%	100,0%	100,0%	100,0%
FEB	89,0%	100,0%	100,0%	100,0%
MAR	85,6%	90,0%	95,5%	68,7%
APR	77,5%	49,7%	77,4%	-0,7%
MAY	73,0%	23,1%	65,4%	-28,3%
JUN	79,2%	29,5%	68,3%	-52,3%

4 CONCLUSION & FUTURE RESEARCH

4.1 Conclusion

In the present work intended, actual and simulated heating and cooling demand were compared based on their calculation methods, input parameters and results.
In order to perform similar calculations, it is necessary to align the input data so that the specific parameters are given for each particular simulation. The procedure is simpler if standard parameters, as they are given for the Energy Certificate, are used but complex and time consuming if they need to be calculated.

For the steady state process, complex correlations such as thermal heat storage capacity of the various components are based on simplified account of multiplication factors, whereas in the simulation this is indicated by detailed building information materials and internal conditions, which is one reason for the different outcomes.

Although the results of the simulated scenarios were always higher except in the summer months, they were still close to the actual heating demand if input data considered the actual system performance. In this case also the simulated Energy Certificate was closer to reality when the savings of the heat exchanger were taken into account.

The higher monthly heating demands of the Energy Certificate compared to the actual loads refer to the higher transmission heat losses and lower solar/internal gains estimated in the standards for the steady state calculation method.

In view of the results, it is obvious that the simulation is far closer to reality as the intended EC heating demands.

Because the energy conversion factors depend on multiple parameters, neither Tas nor Archiphysik were able to accurately calculate the energy consumed for cooling. This was shown by comparing the cooling demand results.

The advantages of the dynamic simulation method in comparison to the steady-state one were therefore closer in the heating demand approach and in the free adjustability of all influencing factors. In particular, the analysis of the consequences of individual design steps and future decisions of the building can be carried out much more accurately with the dynamic simulation.

The previous questions stated in the introduction can be therefore answered as follows:

1. What are the similarities and differences between intended and simulated energy performance?

Both, steady-state and dynamic simulation try to provide the user with the actual energy demand of the designed building. It is obvious that the results cannot be expected to be similar, since both input parameters and calculation methods are very different. It is useful to compare the further development and mutual validation of methods and their according standards.

2. Which simulation parameters have the greatest impact on the heating and cooling demand and why?

It was shown that the internal gains input data have a great influence in both, heating and cooling demand. The most important parameters are infiltration and ventilation rates, because of the energy which has to be used in order to heat or cool the outside unconditioned air. For buildings with a complex air conditioning system, like House B, where the air has to be exchanged at least two times per hour it is a must to take every relevant system setting into consideration and adapt those for the simulation. Furthermore, standard occupancy level, equipment and lighting gains are not accurate adjusted.

3. Does a comparison of actual, intended and simulated outcomes make sense in order to have a sustainable building performance?

In order to choose the adequate heating and cooling system for a building, a system sizing is required. The closer the simulation or the EC are to the actual performance, the better the system can be selected, and therefore no extra downgrade or upgrade is required. By installing the proper building services not only decreases the expenses, but also the energy consumption can be brought to an optimum. Hence this helps protecting the environment and reducing the annually energy consumption and CO2 emissions.

4.2 Future Research

The thematic about simulating the actual and intended demand of the present work, is not only in Austria but also all over the world a subject of constant changes, because of new procedures and standards. Subsequently, the potential of simulation models as a planning tool has to be investigated more in detail, therefore to be used for the evaluation in the planning phase and building design. This would strengthen the building design for the specific proposed use.

A further evaluation of the present research, for example on a weekly basis, considering the simulation of the air conditioning system could be performed, in order to analyze the inaccurate cooling demand results for EC and Tas simulation. Additionally, a weather station could be installed on top of the extension House B for more specific weather parameters. Neglected questions because of missing data, as actual inside temperature and humidity level, could also be answered by monitoring these so as to not only refer to the standard values.

With respect to the Energy Certificate calculation, another solution has to be found to optimize the outcome, especially for non-residential buildings, because the values are too high and therefore lead to an oversized building system, which in turn provides higher energy consumption.

5 LIST OF FIGURES

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7 REFERENCES

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