MASTER THESIS

A Study on the Thermal Performance of School Buildings in Albania

unter der Leitung von

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Abstract

The aim of this research is to illustrate the thermal performance of school buildings in Albania and to study possible improvements. This is done based on the monitoring of indoor environmental conditions and energy simulations of the thermal building performance.

Three schools are selected in different parts in Albania (in Tirana, Vlora and Peshkopi), according to the three recognized climate zones of the country. Indoor environmental parameters, such as indoor temperature and relative humidity, are measured in three representative rooms in the school in Tirana and Vlora, for a 10-week observation period. The measured data is compared to European Austrian standards, and Albanian standards for educational buildings, resulting that both schools experience not a comfortable environment, as outlined by the standards.

The school building in Peshkopi is a new building still undergoing construction. This building has been analysed based on the energy simulation, in order to determine any progress made towards having better environmental conditions according to the standards. For the schools in Tirana and Vlora a calibrated model is built to identify measures for lowering the heating load of the buildings. Results for the two evaluated schools, based on dynamic thermal simulations, indicate relatively low annual heating demand, although there is no thermal insulation applied. However, measured indoor environmental parameters show temperatures below the comfort ranges. Therefore, both thermal insulation and adapted heating operation have to be considered as improvement measures.

Keywords: thermal performance, thermal comfort, insulation, schools, energy simulation, calibration, Albania

Kurzfassung

Das Ziel dieser Arbeit ist es, das thermische Verhalten von einigen typischen Schulgebäuden in Albanien zu untersuchen. Dies wird mittels in-situ Messungen der Innenraumbedingungen, sowie mittels numerischer thermischer Simulation dieser Bauwerke durchgeführt. Auf diese Weise kann der Status Quo in den Simulationen erfasst (kalibriert) werden, und anschließend mittels paremetrischer Studien die Auswirkungen potentieller Verbesserungsmaßnahmen untersucht werden.

Drei Schulen in drei verschiedenen Städten in Albanien (Tirana, Vlora und Peshkopi, ausgewählt nach den drei vorherrschenden Klimazonen des Landes) wurden für diese Untersuchung ausgewählt. Umweltparameter wie Temperatur und relative Luftfeuchtigkeit wurden in drei Bereichen der Schulen in Tirana und Vlora für eine Beobachtungszeit von 10 Wochen gemessen. Diese Daten werden mit den europäischen, österreichischen und albanischen Standards für Bildungsgebäude abgeglichen. Beiden Schulen ist gemein, dass sie keine optimalen Innenbedingungen aufweisen, speziell im Vergleich mit den Angaben aus einschlägigen europäischen und österreichischen Standards.

Die dritte Schule (in Peshkopi) ist ein neues Gebäude, welches sich noch in der Bauphase befindet. Dieses Gebäude wurde mittels thermischer Simulation analysiert und die so erhaltenen Performancedaten mit den Normen verglichen.

Ein kalibriertes Modell ist für die Schulen in Tirana und Vlora erstellt worden. Die Ergebnisse der dynamischen thermischen Simulationen zeigen, dass trotz der fehlenden Wärmedämmung ein relativ geringer jährlicher Heizwärmebedarf vorliegt. Dies ist aber zum Teil den sehr widrigen Innenbedingungen hinsichtlich thermischen Komfort geschuldet. Aus diesem Grund sind bei potentiellen Optimierungen sowohl die Verbesserund der thermischen Hülle, wie auch eine angepasste Heizungsoperation anzudenken.

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Dedicated to my parents and Adea Liv

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1. Introduction

1.1 Motivation

If you are thinking a year ahead, sow a seed.
If you are thinking ten years ahead, plant a tree.
If you are thinking one hundred years ahead, educate the people.
—Chinese proverb

The thermal performance of school buildings is an important issue for the thermal comfort of the students and teachers occupying them: *"An environment that includes appropriate lighting, sound, temperature, humidity, cleanliness, colour, and air quality can help students learn better. In many cases, improving these attributes can additionally reduce energy use"* (ASHRAE 2011).

The majority of school buildings in Albania can be considered to be in bad condition, according to Ministry of Education and Science (2002). This status quo manifests itself by bad thermal performance and high transmittance losses, lack of adequate heating operation and corresponding devices, and is resulting in inadequate environment for learning and teaching activities. Students presumably lose concentration and become tired in overheated rooms, or might have difficulty performing tasks when the inside environment is cold. Retrofit efforts of existing school buildings in Albania generally focus on creating new spaces, or on improving the existing situation of the classrooms and laboratories (including electrical, plumbing installations, etc.). However, this is often done without appropriate integration of thermal insulation to the buildings' envelopes. Such efforts would not only improve the indoor environment conditions, but also help to reduce the operational heating cost.

1.2 Objective

The objective of this research is to provide an overview of the thermal performance of school buildings in Albania and to analyse possible improvements. This study focuses on three school buildings: Two existing school buildings with non-insulated building envelopes, and one new building, which is currently under construction (including insulated building envelope). These schools are located in different cities in Albania (Tirana, Vlora and Peshkopi). These cities are in different climatic zones of Albania, according to the three recognized climate zones of the country (Qendra e publikimeve zyrtare 2008).

The research efforts involve monitoring and evaluation of thermally relevant indoor conditions in the two existing schools (in Tirana and Vlora). For these schools, simulation and evaluation of alternative thermal improvement situations is performed. The results will illustrate the thermal performance of the assessed schools and will help to suggest improvements for reaching a more comfortable environment for teachers and students according to the standards.

The third school building in Peshkopi is a new building still under construction. Therefore the evaluation of this school was based on energy simulations. Similar to the existing schools, parametric studies were performed to identify and evaluate potential improvement suggestions.

1.3 Background

1.3.1 General Overview

The Republic of Albania lies on the west of the Balkan Peninsula and on the east coasts of the Adriatic and Ionian seas. The geographic borders of Albania can be defined via a northern-most geographical latitude of 42° 39' (Vermosh), southern-most geographical latitude of 39° 38' (Konispol), eastern-most geographical longitude of 21° 40' (Vernik village, Devoll) and western-most geographical longitude of 19° 16' (Sazan island). The country shows north-south-extent of 340 km, and east-west-extent of 148 km (Qiriazi 2006, p.9).

Albania has 2,876,591 inhabitants (INSTAT 2017) in an area of 28,748 km^2 (INSTAT 2011).

The majority of buildings in Albania are considered to have been built with little concern for energy efficiency (Exergia Consulting Team 2008). Prior to 1990 the central target of building construction focus on low investment cost. The necessities for shorter construction periods and low cost housings resulted in buildings without thermal insulation. The majority of the buildings were massive building constructions based on reinforced concrete. Approximately 60% of the prefabricated buildings of the construction period, between 1950 and 1975, show rather high energy consumption profiles. The buildings erected in later years show a better thermal performance, but still feature only minimum insulation and regularly utilize electricity for thermal conditioning of the buildings.

According to INSTAT (2010) there are 3,907 educational buildings including kindergartens, private sector schools, elementary and secondary-schools, high schools and higher-education faculties in Albania (see Appendix). 1,605 of these educational buildings are Primary and Secondary schools (known as “shkolla 9-vjecare” in Albania).

This study focuses on the thermal performance of primary and secondary (middle) schools. These buildings host the compulsory education in Albania, and thus represent the major number of school buildings within Albania. According to the Ministry of Education and Science (2002), school buildings built prior to 1990 are generally in bad condition due to lack of investments. This can be observed particularly by the large number of pupils in a classroom, small dimensions of windows (lack of natural light), absence of thermal and acoustical insulation, lack of ventilation possibilities, old or malfunctioning heating system, and the poor quality of electrical and hydraulic installations. Only few of these schools meet the criteria to which schools should be designed and constructed (Ministry of Education and Science 2002). In school buildings retrofitted after 1990, an evident improvement can be noted regarding the quality of construction and implementation of some standards and criteria. Needless to say, these improvements require further expansion. Therefore, a list of standards and criteria has been compiled, based on recent experiences in Albania and with reference to corresponding standards and criteria applied in the Western European countries.

1.3.2 Economic profile of Albania

Albania has experienced large political, institutional and socio-economic changes, during the years of democracy since 1992. From a deeply isolated country of constitutionally deprived freedoms and enforced atheism, Albania changed into a country of political pluralism (Republic of Albania Council of Ministers 2008). According to the MOEFWA (Ministry of Environment, Forest and Water Administration 2005), the first five years of the transition, from 1992 to 1997, culminated with the internal crisis due to pyramid schemes, which strongly damaged the economy. This crisis was reflected in the drastic fall of the production as a result of the massive shutdown of inefficient state-owned companies and the collapse of the agricultural production. The energy sector used to be one of the most important sectors for the Albanian economy. The country has a large variety of energy resources varied from oil and gas, coal and other fossil fuels, to hydropower, natural forest biomass and other renewable energy sources. The natural gas sector has slowly reduced since the beginning of 90's, whereas the oil sector remains constant due to imported oil products. The primary energy supply dropped by more than 50% in 1992, from the peak of 2.26 Mtoe in 1990 to 1.22 Mtoe. Ever since, from 2001, the main energy supply has remained relatively stable around the level of 1.84 Mtoe. The consumption of the energy sources in all economic sectors is shown in Figure 1 and 2, during 1985 - 2002. The electricity sector is the most significant energy sub-sector, where more than 90% of electricity generation comes from hydro energy sources.

The major energy consuming sub-sectors in Albania are the public buildings and the households, consuming mainly large quantities of electricity, fuel, wood and LPG to provide the space heating. Over the past few years, in Albania, the electricity is consumed increasingly for air-cooling as well (Albania Energy Efficiency Centre 2007).

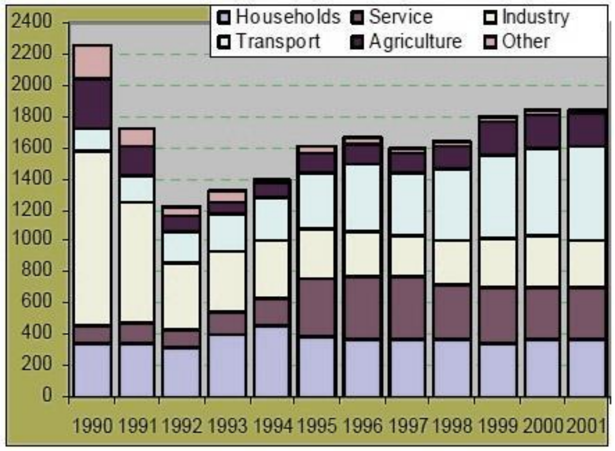

Figure 1 Contribution of each sector in energy consumption (in ktoe) from 1990 to 2001 (MOEFWA 2005)

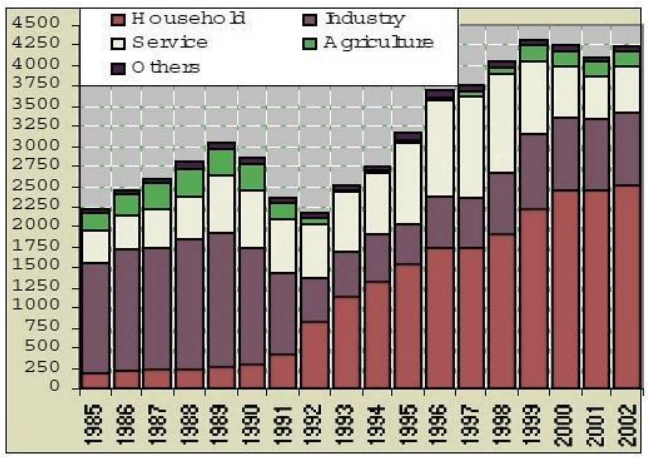

Figure 2 Electricity consumption (in GWh) according to economic sectors from 1985 to 2002 (MOEFWA 2005)

1.3.3 Climatic conditions of Albania

Albania has Mediterranean climate with dry, hot summers, generally extended periods of sunshine, and wet cool winters. The country has different climate conditions because of the rugged relief of the regions, with different heights from the sea level (Qiriazi 2006).

The country is divided in four main climate areas: field Mediterranean area, hilly Mediterranean area, pre-mountainous Mediterranean area and mountainous Mediterranean area (Figure 3), causing several climatic conditions although being a relatively small country. The coastal lowlands have typically

Mediterranean weather; the highlands have a Mediterranean continental climate. The weather in Albania varies significantly from north to south (IHM 1978).

According to climate zones in the function of Grade-Days the territory of the country is divided in three main climate zones: Zone I - less than 1500, Zone II - from 1501-2500 and Zone III - higher than 2500 (Figure 4).

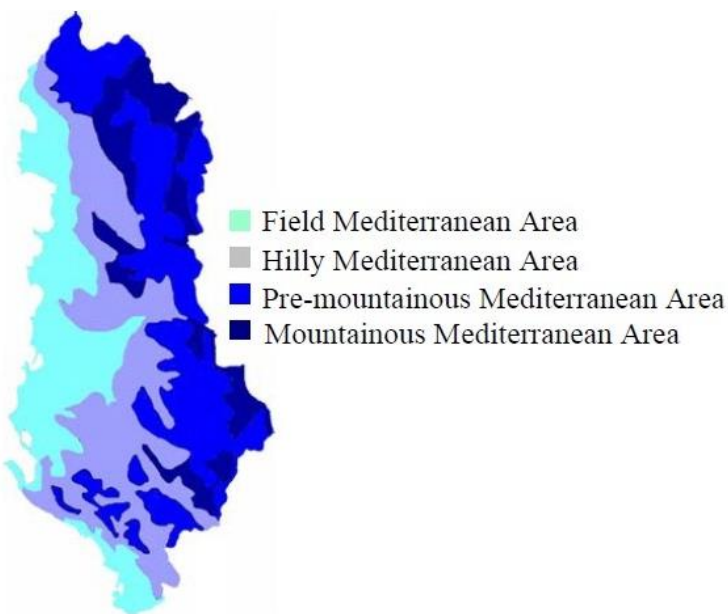

Figure 3 Climate areas division in Albania (IHM 1987)

Figure 4 Three climate zones in the function of Grade-days (Qendra e publikimeve zyrtare 2008)

The distribution of outdoor air temperatures in Albania has a considerable variability. Mean annual outdoor temperature varies from 8 °C to 9 °C in the mountainous area and up to 17 °C in the seaside south-west aera. Mean monthly outdoor temperature, measured during the period from 1961 to 2000, is displayed in Figure 5 (Mustaqi and Sanxhaku 2006).

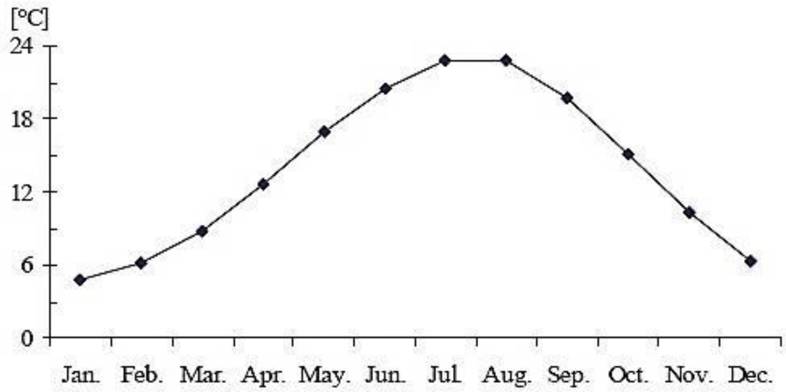

Figure 5 Mean monthly outdoor temperature of the main cities in Albania during 1961 – 2000 (Mustaqi and Sanxhaku 2006)

Rainfall is mainly active during winter averaging from 65% to 75% of the annual quantity (Figure 6). The annual precipitation varies from 650 mm in the south-east to 2800 mm in the Alps of Albania, with the average yearly precipitation for the whole territory at approximately 1400 mm (IHM 2006).

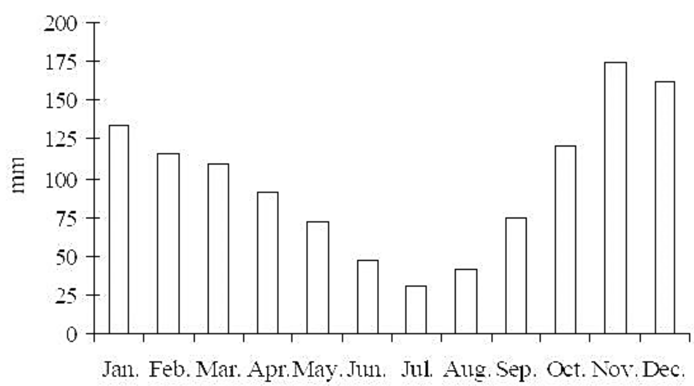

Figure 6 Mean monthly precipitation in the main cities in Albania during 1961 – 2000 (IHM 2006)

The Population density in Albania according to Census preliminary results (2011) is 98.5 people per km² (Figure 7). Nearly two - thirds of the population are concentrated in the West, especially in Tiranë - Durrës region. Tirana has the highest value of 10533 people per km², while the lowest value is 1.8 people per km² measured in Leskovik, (municipality in Kolonjë District), located in south-eastern Albania.

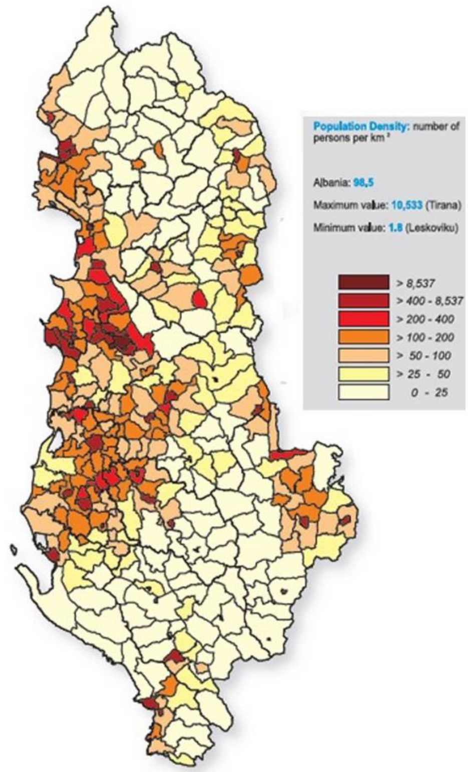

Figure 7 Population density map of Albania (Census-Al 2011)

According to Bruci (2008) the outdoor temperatures in Albania demonstrated decreasing trend from 1961 until the 1985; however the outdoor temperatures have been increasing since then. From 1985 the amount of the hot days with temperatures exceeded 35 °C has been increased, whereas the cold days with temperatures below –5 °C have been decreased.

1.3.3.1 Climatic conditions of Tirana

Tirana is the capital and the largest city in Albania, consisting of an area of 1,652 km² with a population of 749,365 (INSTAT 2011). This city is the administrative, cultural and economic centre of the Republic of Albania. Tirana is situated on the western center of the country surrounded by hills at an altitude of 110 metres above sea level. It has a Mediterranean climate with dry hot summers and mild winters (IHM 2006). Figures 8 and 9 illustrate the mean monthly outdoor temperature and precipitation in Tirana over the period 1961 to 2006.

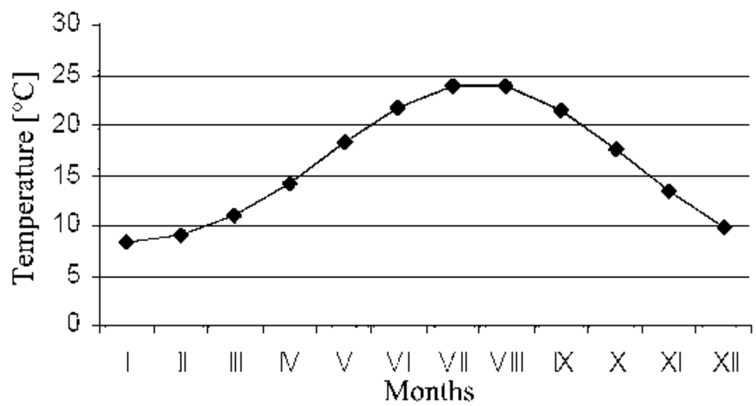

Figure 8 Mean monthly outdoor temperature of Tirana during 1961 – 2006 (IHM 2006)

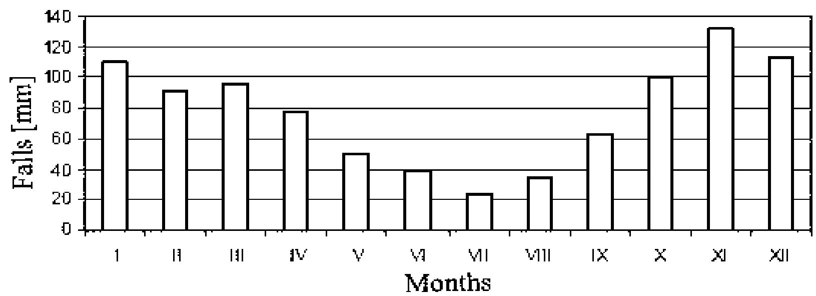

Figure 9 Mean monthly precipitation of Tirana during 1961 – 2006 (IHM 2006)

1.3.3.2 Climatic conditions of Vlora

Vlora has 175,640 inhabitants in an area of 2,706 km² (INSTAT 2011). This city lies in the south-western coastal region of Albania, at the southern end of the Adriatic Sea and the northern part of the Ionian Sea at an altitude of 4 metres above sea level. Vlora is the second major sea port after Durres. It has typical climate of Mediterranean Sea, with mild wet winters and dry summers (IHM 2006). Figures 10 and 11 show the mean monthly outdoor temperature and precipitation in Vlora, from 1961 to 2006.

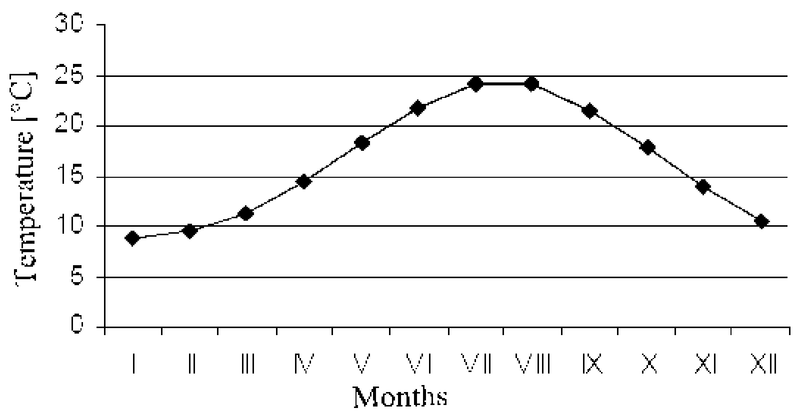

Figure 10 Mean monthly outdoor temperature of Vlora during 1961 – 2006 (IHM 2006)

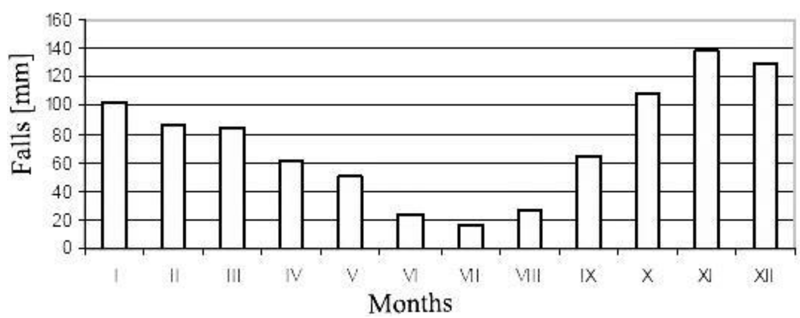

Figure 11 Mean monthly precipitation of Vlora during 1961 – 2006 (IHM 2006)

1.3.3.3 Climatic conditions of Peshkopi

Peshkopi is the largest and the most important city of Dibra region, with a population of 137,047, consisting of an area of 2,586 km² (INSTAT 2011). This city is located in north-eastern part of Albania at an altitude of 657 metres above sea level. Peshkopi has pre-mountainous Mediterranean climate with warm summers and cold winters. Figures 12 and 13 show the mean monthly outdoor temperature and precipitation in Peshkopi, from 1961 – 2006.

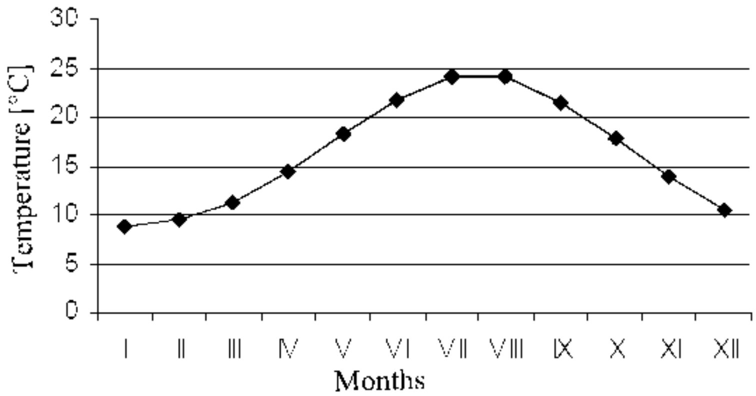

Figure 12 Mean monthly outdoor temperature of Peshkopi during 1961 – 2006 (IHM 2006)

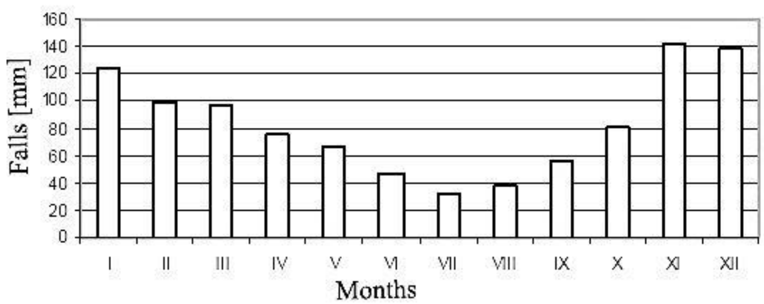

Figure 13 Mean monthly precipitation of Peshkopi during 1961 – 2006 (IHM 2006)

1.3.4 Albanian thermal environment standards for educational building

There are few normatives about thermal comfort in the Albanian Standards Regulation. There is a contemporary regulation code "*ENERGY SAVING ON BUILDINGS*" item 5, according to the Law No. 8937 published by the law act Decision of Council of Ministers (DCM) No.38 (2003). This code includes a detailed analysis for the determination of atmospheric conditions (grade-days, outdoor temperatures of each cities of Albania and so on).

All buildings shall be constructed in respect to the normative coefficient of thermal volumetric losses (Gv_t). The overall coefficient of thermal volumetric losses is introduced Gv_t [$Wm^{-3}K^{-1}$], based on the three climatic zones of the country's regions (cold, coastal and warm zone) and determines building thermal losses in terms of conductivity and ventilation.

The coefficient of thermal volumetric losses Gv [$Wm^{-3}K^{-1}$] depends mainly on the volume of the building, window to wall ratio, the structural design of the building and the difference between indoor and outdoor temperature. Gv_t should not exceed $Gv_{t,0}$ normative values which are recommended in the climate zones and building characteristics, for i.e.: $Gv_t \leq Gv_{t,0}$ (Qendra e publikimeve zyrtare 2008).

1.3.4.1 Internal air temperature

Internal air temperature in specific rooms should be measured in the central part at a height 1.50 m from the floor and in a way that the measuring instrument is not influenced by any radiation (Ministry of Education and Science 2002).
The internal air temperature of the main rooms of the school buildings, according to the Ministry of Education and Science (2002), should be as shown in Table 1.

Table 1 Internal air temperature of the main rooms in the school buildings (Ministry of Education and Science 2002)

Environments	Temperature [°C]
Classrooms, library, administrates' room	+20
All working places and laboratories	+12 till +18
Gym, halls, corridors	+16
Doctor's room	+22

Heating elements (radiators) should be placed 15 cm below the window, in order to avoid any window condensation. The amount of radiators placed in a specific space depends on the floor area of the room and the radiators technical specifications.

1.3.4.2 Ventilation

According to the Ministry of Education and Science (2002), the necessary air exchange in a classroom should be changed at least 4 times in a volume of 5 m^3 per student.
Ventilation can be natural and mechanical for special cases.

a) Natural ventilation is through opening the windows.
b) Mechanical ventilation is a part of natural ventilation, usually used in labours and workshops.

1.3.5 European thermal environment standards for educational building

1.3.5.1 Thermal comfort

"*Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment. Because there are large variations, both physiologically and psychologically, from person to person, it is difficult to satisfy everyone in a space. The environmental conditions required for comfort are not the same for everyone. However, extensive laboratory and field data have been collected that provides the necessary statistical data to define conditions that a specified percentage of occupants will find thermally comfortable*" (ASHRAE 2004).

Thermal comfort is measured by the air temperature, as well as by the number of people complaining about thermal discomfort. The most frequently used indicator of thermal comfort is air temperature, because it is simple to use and most people can relate to it. However, air temperature should always be handled in relation to other environmental and personal factors. Personal factors (metabolic rate, clothing) combined with environmental factors (air temperature, air movement, humidity and radiation) influence what is described as 'thermal comfort'.

Furthermore thermal comfort is influenced by the floor surface temperature and associated elements such as radiant asymmetry mean radiant temperature and operative temperature. Localized discomfort due to cold and warm floors wearing normal foot wear and stocking feet is addressed in the ISO 7730 and ASHRAE 55 (2005).

The recommended minimum acceptable category A for classrooms in winter (Table 2), as defined in EN ISO 7730 is 22 °C ± 1°C and for the summer season 24,5 °C ± 1 °C. According to Szokolay (2004) a comfortable range for indoor relative humidity ranges from 30% to 65%.

Table 2 Example design criteria for spaces in various types of building (ISO 7730 2005)

Type of building/space	Activity W/m2	Category	Operative temperature °C		Maximum mean air velocity [a] m/s	
			Summer (cooling season)	Winter (heating season)	Summer (cooling season)	Winter (heating season)
Single office Landscape office Conference room Auditorium Cafeteria/restaurant Classroom	70	A	24,5 ± 1,0	22,0 ± 1,0	0,12	0,10
		B	24,5 ± 1,5	22,0 ± 2,0	0,19	0,16
		C	24,5 ± 2,5	22,0 ± 3,0	0,24	0,21 [b]
Kindergarten	81	A	23,5 ± 1,0	20,0 ± 1,0	0,11	0,10 [b]
		B	23,5 ± 2,0	22,0 ± 2,5	0,18	0,15 [b]
		C	23,5 ± 2,5	22,0 ± 3,5	0,23	0,19 [b]
Department store	93	A	23,0 ± 1,0	19,0 ± 1,5	0,16	0,13 [b]
		B	23,0 ± 2,0	19,0 ± 3,0	0,20	0,15 [b]
		C	23,0 ± 3,0	19,0 ± 4,0	0,23	0,18 [b]

"*For given values of humidity, air speed, metabolic rate, and clothing insulation, a comfort zone may be determined. The comfort zone is defined in terms of a range of operative temperatures that provides acceptable thermal environmental conditions or in terms of the combinations of air temperature and mean radiant temperature that people find thermally acceptable*" (ANSI/ASHRAE 2004, p.4). The average indoor temperature θ_i shown in Table 3 (ÖNORM B 8110 2011) should be accepted as criteria.

Table 3 Average indoor temperature (ÖNORM B 8110 2011)

Building dedication:	**θ_{ih} [°C]**
housing, office, school buildings	20
hospitals, nursing homes	22

Table 4 illustrates the guideline of energy characteristics of buildings from the Austrian Institute of Building Technology.

Table 4 Guideline of Energy Characteristics of Buildings from the Austrian Institute of Building Technology (OIB-RIL. 6 2015)

Building constructions	**U-values [**$Wm^{-2}K^{-1}$**]**
Exteriors walls	0.35
Basement floor slabs	0.4
Windows (non-residential building)	1.7
Exteriors doors	1.7
Roofs	0.2

1.4 Structure

This study is structured in terms of seven sections.

Section 1 deals with the objective and motivation reasons. It outlines the background of the project, describes the social, economic and environmental overview of the country and displays the European and Albanian standards of educational building. Section 2 describes the methodology, collection of data and measuring equipment. Section 3 includes the results and the discussions by analysing as well the content of the results. Section 4 finales the analysis and opens the perspective for future research. This is followed by section 5 with references, section 6 with appendices and section 7 with list of figures and tables.

2. Approach

2.1 Overview

This approach contains data collection regarding:

- local climate
- indoor conditions of the assessed school buildings in Tirana (school A) and Vlora (school B)
- building materials and construction details
- ventilation regimes
- occupancy patterns

Indoor environmental parameters, such as air temperature and relative humidity, are measured in two representative classrooms and in an office space, for 10 weeks observation period. A digital simulation model of each school is generated and calibrated, based on the collected indoor climate data.

The selected school in Peshkopi (school C) is recently erected. This school has been analysed based on the energy simulation, in order to define any progress made towards having better environmental conditions according to European and Albanian standards.

2.2 Building documentation

2.2.1 School building in Tirana (school A)

Tirana is the biggest city in Albania and, compared to the other Albanian cities, has the largest percentage of students in its population. For this research is chosen the secondary school “Kushtrimi i Lirise” (school A). The school‘s position is indicated in the map in Figure 14.

Figure 14 Aerial view of school A outlined in red (source: Google 2017)

This school is located in the street "Ali Demi" at municipal unit No. 1, surrounded by residential buildings. The building has a regular geometric shape and is covered with a sloping roof.

School A, built in the year 1963, was partially reconstructed in 2000 (Figure 15) and retrofitted in 2008 (Figure 16).

Figure 15 View of the south façade of school A, retrofitted in 2000 (source: wikimapia 2017)

Retrofit effort of the existing building focused on creating new spaces and improving the existing situation of the classrooms and laboratories (including electrical, plumbing installations, etc) and on installing a central heating system. An additional three storeys was built, next to the existing building, for the pre-school children.

Figure 16 View of the south façade of school A since 2008 (source: wikimapia 2017)

On the ground floor there are eight classrooms with a floor area of 38.6 m^2, a small classroom (25 m^2), a dental treatment room, a cafeteria for students and teaching staff, a gym, two toilets and a main hall immediately after the stairs.

On the first and the second floor there are six classrooms, two laboratories, an administrative meeting room, a library and two toilets.

In the additional three storeys there are six classrooms (two classrooms per each floor) and two offices.

The building is constructed with brick retaining walls, 38 cm thick, without thermal insulation. The school has double-glazed duralumin frame windows and wooden doors.

There are three radiators installed in each classroom, positioned adjacent to the windows (Figure 17 and 18), and two radiators in each office.

Figure 17 Radiators installed in school A (source: own picture)

Figure 18 View of a classroom in school A (source: own picture)

School A is operating from 8:00 to 17:00 every weekday. Most of the classrooms function from 8:00 to 13:00. Due to the lack of classrooms a second shift from 13:10 - 17:00 is needed, where approximately 30% of the classrooms operate. Today the school has a gross floor area of 2891 m² and 976 students, with 30 to 33 students per class.

2.2.2 School building in Vlora (school B)

The school “Musa Cakerri” (School B) is located near the centre of the city. The school’s position is indicated in the map in Figure 19.

Figure 19 Aerial view of school B outlined in red (source: Google 2017)

Figure 20 North façade of the school B (source: own picture)

Figure 21 South façade of the school B (source: own picture)

School B, built in 1975, is partially reconstructed in 2005 (Figure 20). The building has single-glazed windows with plastic frames and wooden doors, with brick walls 25cm thick, without thermal insulation.

Similarly to school A, school B is operating from 8:00 - 17:00 every weekday. Most of the classrooms function from 8:00 - 13:00 and approximately 30% of the classrooms operate from 13:10 - 17:00.

There is no central heating system installed. Most of the classrooms aren't heated. Some of them are heated by the electrical equipment or by the air conditioners installed by a few parents of the students. The school has 24 classrooms, including laboratories. There is an open sports area facing south illustrated in Figure 21.

The building has a gross floor area of 1568 m² and 760 students, with 30 - 32 students per class.

2.2.3 School building in Peshkopi (school C)

School building in Peshkopi (school C) is a new building still undergoing construction. This project was part of a bidding procedure for constructing a few new schools in Albania, organized by the Ministry of Education and Science (Ministria e Arsimit dhe Shkences 2007) and financed by World Bank.

Figure 22 Plan of site of school C (Ministria e Arsimit dhe Shkences 2007)

The building has a U-shape, illustrated in Figure 22, with the main entrance facing south-west. Figures 23 to 25 provide an overview of school C.

Figure 23 3D image of school C (Ministria e Arsimit dhe Shkences 2007)

Figure 24 View of the construction site of school C, facing east (source: own picture)

Figure 25 View of the construction site of school C, facing north-west (source: own picture)

The building has three floors. The staircase and the halls are situated in centre of the floor. Figures 26 to 28 illustrate the floor plans of school C. The building has a gross floor area of 4350 m².

Figure 26 Ground floor plan of school C (Ministria e Arsimit dhe Shkences, 2007)

Figure 27 First floor plan of school C (Ministria e Arsimit dhe Shkences, 2007)

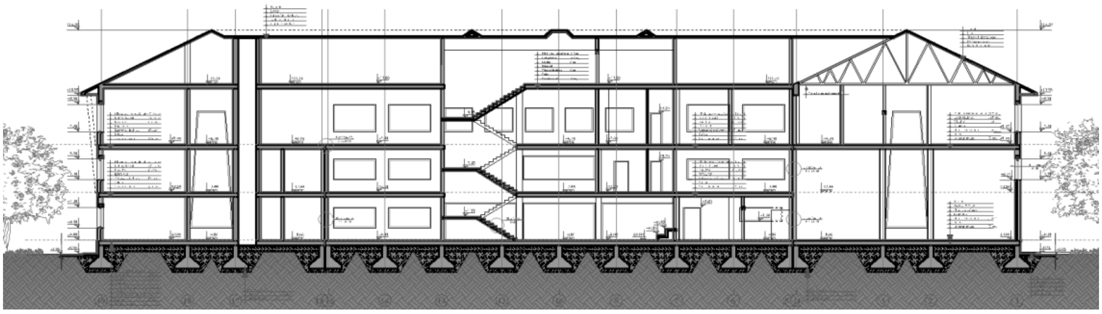

Figure 28 Section of school C (Ministria e Arsimit dhe Shkences, 2007)

This building is designed in accordance to the standards, including ramps and a lift for the persons with disabilities. Traditional architectural elements are incorporated in the façade, such as decorative bricks. This school has 24 classrooms (each classroom has a floor area of 50m²), four laboratories, three cabinets and a library, and will have approximately 720 students.

2.3 Measurements

Measurements of indoor temperature and humidity were carried out in schools A and B during ten weeks, from February 2012 to April 2012. Indoor temperature, relative humidity and light intensity were measured by using hobo data loggers. Three loggers were placed in three different rooms inside the buildings, in two classrooms (with different orientation) and in an office. Measurements in school B have been carried out from 09.02.2012 to 18.04.2012 and in school A from 16.02.2012 to 25.04.2012.

2.3.1 Measurement equipment

The HOBO® U12 data loggers (Figure 29) were used for the measurements. This equipment has internal sensors to assess indoor temperature, relative humidity and lighting levels (Table 5).

Data-loggers were set to log every 15 minutes the state of the three parameters. The collected data were downloaded every two weeks by using GreenLine software. This software was used to read out data, to export data as 'TXT' files, launchings sensors for the next measurements and see the status of the logger.

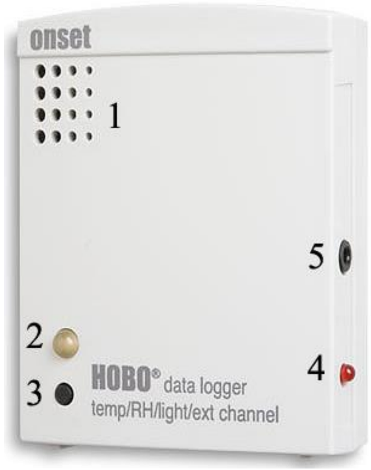

Figure 29 HOBO data logger (ONSET 2012)

1. relative humidity / temperature sensor
2. illuminance sensor
3. reset button
4. LED operation indicator
5. USB port

Table 5 Key specifications of HOBO sensor/logger

Internal sensor	Measurement range
Temperature	-20 °C to 70 °C
Relative humidity	5 % to 95 %
Light intensity	12 lx to 32,000 lx

2.3.2 Data logger locations in school A and B

Data logger locations in school A are displayed in Figures 30 to 34. The sensors were fixed on the wall with duct tape.

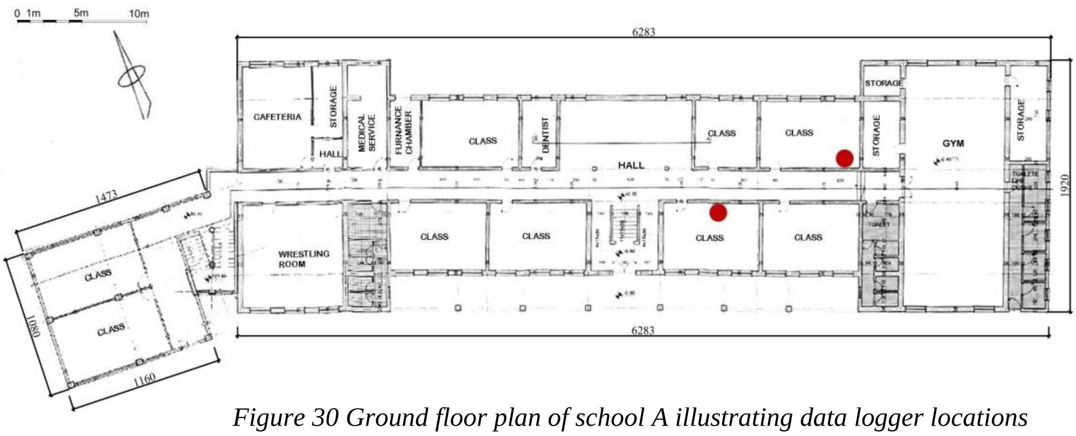

Figure 30 Ground floor plan of school A illustrating data logger locations

Figure 32 Hobo sensor position in the classroom facing north, in school A (source: own picture)

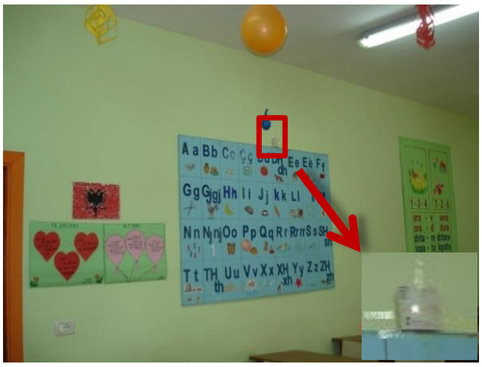

Figure 31 Logger position in the classroom facing south, in school A (source: own picture)

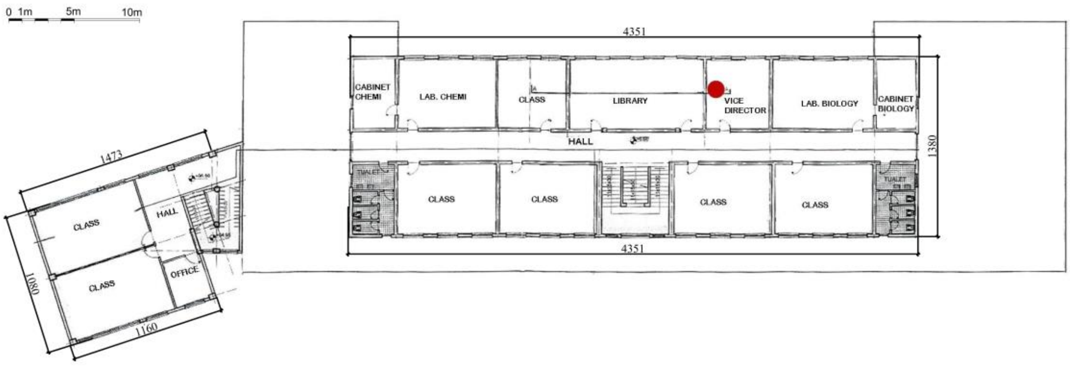

Figure 33 Second floor plan of school A illustrating data logger location

Figure 34 Hobo sensor position in the selected office in school A (source: own picture)

Data logger locations in school B are illustrated in Figures 35 to 40.

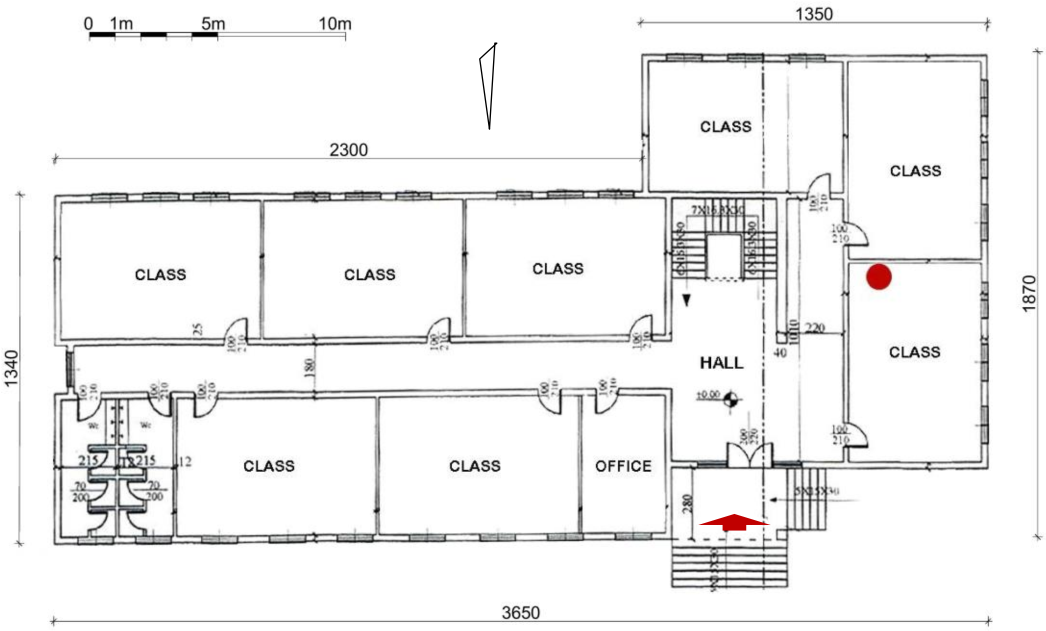

Figure 35 Ground floor plan of school B illustrating data logger location

Figure 36 Hobo sensors position in the classroom facing west, in school B (source: own picture)

Figure 37 View of the classroom facing west, in school B (source: own picture)

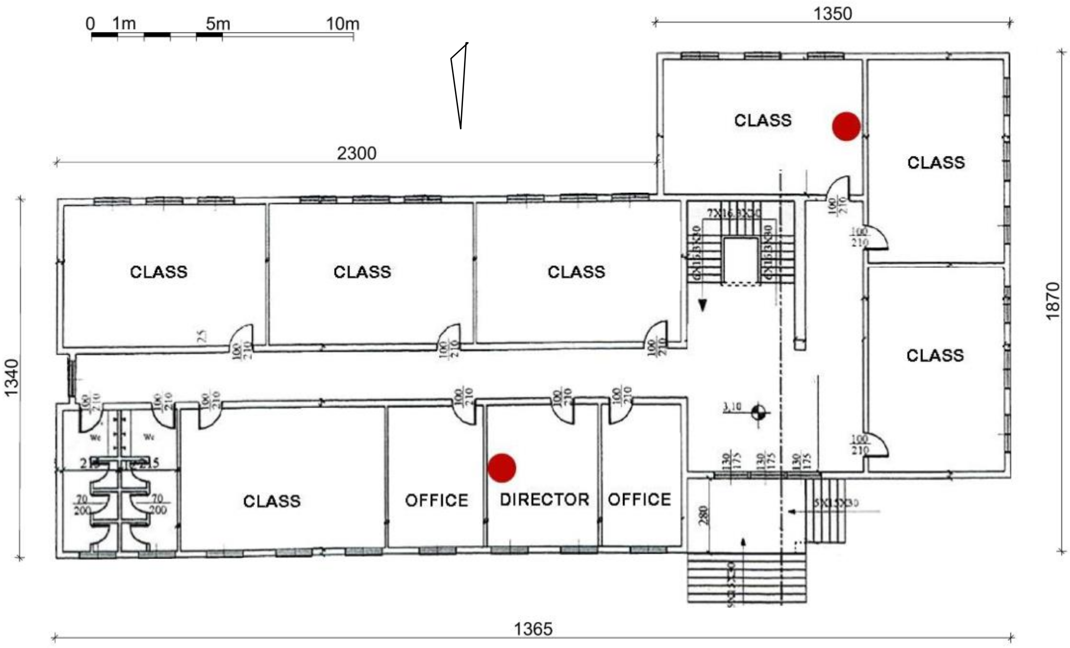

Figure 38 First floor plan of school B illustrating data logger location

Figure 40 Hobo sensors position in the classroom facing south, in school B (source: own picture)

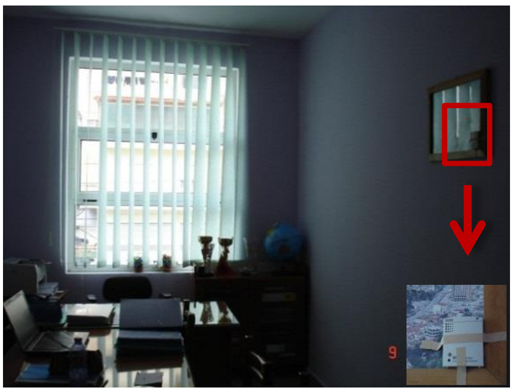

Figure 39 Hobo sensor position in the Principal's office, in school B (source: own picture)

To have more accurate measurements, the sensors in both evaluated schools, are placed on the walls away from windows and doors and not being reachable from the students .

2.4 Exterior weather data

According to the Ministry of Environment, Forest and Water Administration of Albania (2005), monitoring of meteorological elements in Albania has been started since the end of the 19th century and established in the 1950s. Prior to 1980 there were 230 meteorological stations, in 1990 the national meteorological network in Albania is reduced drastically and currently includes 126 meteorological stations. The current measurement technology used for some meteorological elements is very old and measurement inaccuracy is significant. The Institute of Hydro Meteorology (IHM) controls the actions from local stations to the collection and processing. The way of transmission of the meteorological data from stations to IHM is diverse. In some stations data transmission is made by phone in a daily basis for the minimum and maximum air temperature and precipitation. In some other stations the monthly measured data are transmitted to the centre (IHM) one month later by mail.

All the hydro meteorological information sent to the Institute by mail, is archived after processing. The meteorological archive contains data of air temperature (minimum, maximum, mean air temperature), precipitation (daily, monthly, yearly amount), wind, sunshine radiation, humidity, and so on. IHM is making currently efforts to build a minimum network with automatic meteorological and hydrological stations in order to transmit in distance and in real time.

2.5 Weather file

These meteorological data from local meteorological station are not sufficient for the simulation that requires statistics based on an hourly data including:

- dry bulb temperature
- global solar radiation
- diffuse solar radiation

- cloud cover
- relative humidity
- wind speed
- wind direction

Therefore, usage of data generated by Meteonorm (Meteotest 2012) is necessary. This program integrates meteorological data and calculation procedures to develop weather information for a given place based on data measured by local weather stations. Detailed weather data for the cities of Tirana, Vlora and Peshkopi are illustrated in Table A-6, A-7 and A-8 (see Appendix).

The weather data for Tirana, provided from ura e Tabakeve ITIRANAT2 (2012), is used to compare the outdoor air temperatures for calibrating the model. The outdoor air temperature is measured every five minutes, from the nearest weather station of the selected school (located in ura e Tabakeve). Relative humidity, air temperature, wind speed, cloud cover and the dew point are measured from this weather station. Nevertheless these data are not detailed enough regarding the global solar radiation and diffuse solar radiation; therefore for the simulation is used the synthetic weather file generated via Meteonorm.

2.6 Simulation

2.6.1 Data processing

Excel tables are used to merge the collected data from the sensors into hourly values. The occupancy data of the schools was set based on the local observations and the information given by staff of the two operating schools. Occupancy hours are considered from 8:00 – 13:00 and for 30% of the classrooms from 8:00 - 17:00 excluding the weekend and the official holidays.

The monitored data, indoor air temperature and relative humidity, was plotted in psychrometric charts to compare the measured data with the recommended values. In order to evaluate the energy savings, rough estimations regarding the heating demand, resulting from the introduction of thermal insulation in selected school buildings, is used the software tool TAS.

2.6.2 TAS simulation software

TAS (Thermal Analysis Software) is developed by Environmental Design Solutions Limited. TAS Building Simulator (EDSL TAS 2016) is a software tool which simulates the thermal performance of buildings (Figure 41). The main applications of the program are in assessment of environmental performance, natural ventilation analysis, prediction of energy consumption, plant sizing, analysis of energy conservation options and energy targeting.

This program has a modular design and is split into three main programs, the 3D Modeller, Building Simulator and Results Viewer (Figure 42). TAS Building Simulator is linked to the TAS 3D Modeller. Together these two programs are called TAS Building Designer.

The simulation process itself generates a set of hourly results, which are saved to a simulation data file (TSD). The file opens automatically in the TAS Results Viewer. The results can be checked in graphical and tabular format in Results Viewer and then this data can be imported to Microsoft Excel for further processing.

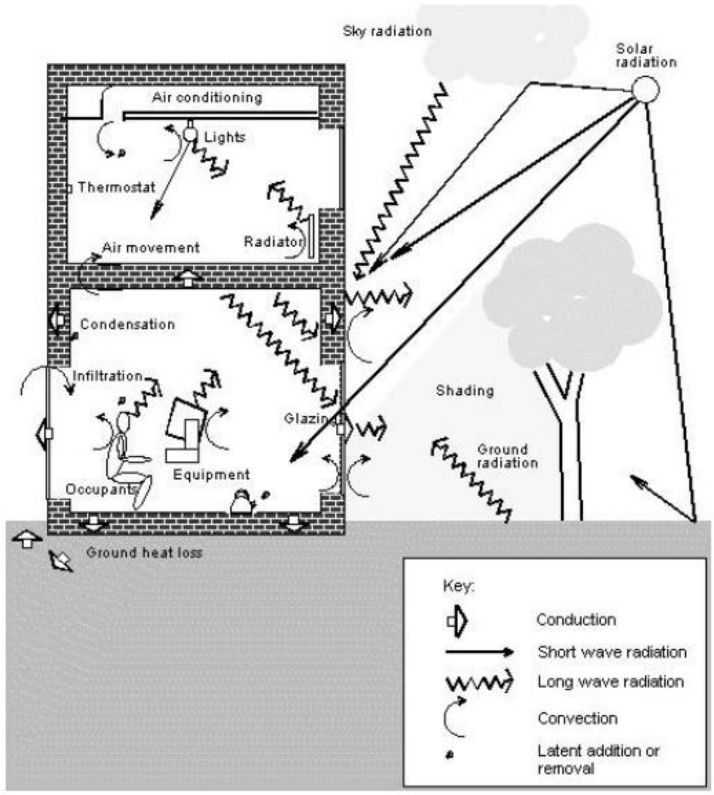

Figure 41 Schematic Representation of Heat Transfer mechanism in a Building (EDSL TAS 2016)

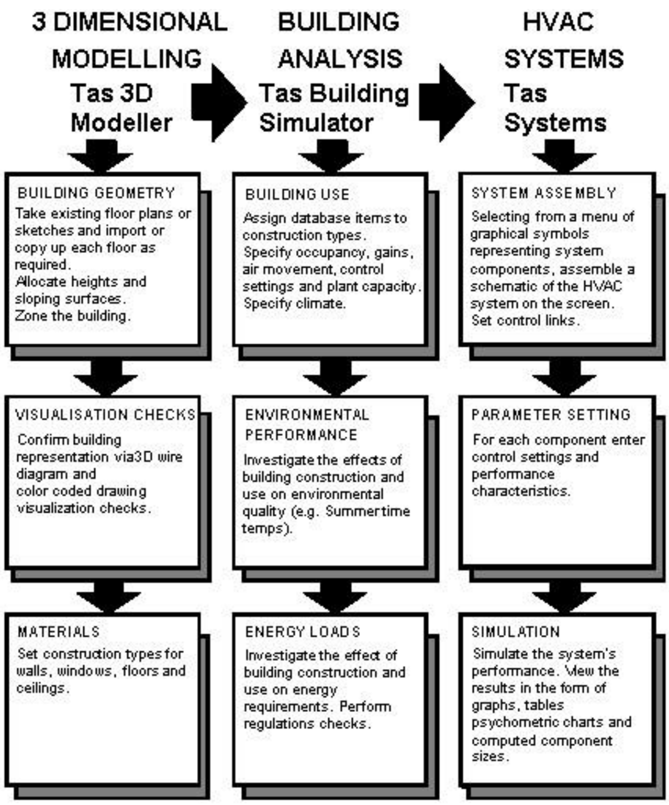

Figure 42 Building Thermal Design Sequence (EDSL TAS 2016)

2.6.3 Building model

The initial simulation models of the selected school buildings were generated based on the collected data regarding orientation (altitude and location), weather data, infiltration, internal gains (light, equipment and occupancy), calendar (dividing monthly, working days, weekends and holidays), schedules (occupancy hours), construction materials and geometry of the building. No heating is applied for the initial simulation model. Figures 43 to 45 illustrate school A, B and C being modelled in TAS.

Different zones are defined in the building, after modelling it in TAS, due to the properties of the space. Zones are named based on the function, floors, orientation of the rooms and where the sensors are placed. In Appendix (see Table A-9 to A-11 and Figure A-7 to A-11) are shown the model of the schools divided into zones.

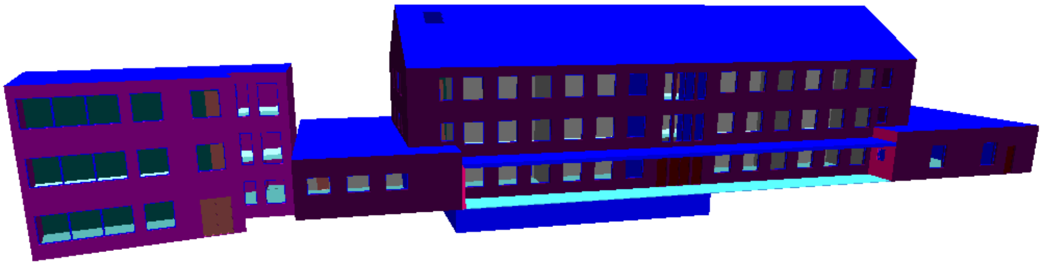

Figure 43 School A being modelled in TAS

Table 6 Thermal properties of construction elements for school A

Construction element	**U-values [$Wm^{-2}K^{-1}$]**
Basement floor	0.5
Floor to the ground	0.3
External wall (38 cm)	1.2
Internal wall (25 cm)	1.5
Upper floor / ceiling	0.5
Flat roof	0.2
Pitched roof	0.2
Windows pane	1.8
Windows frame	1.6
External doors pane	1.9
External doors frame	1.3

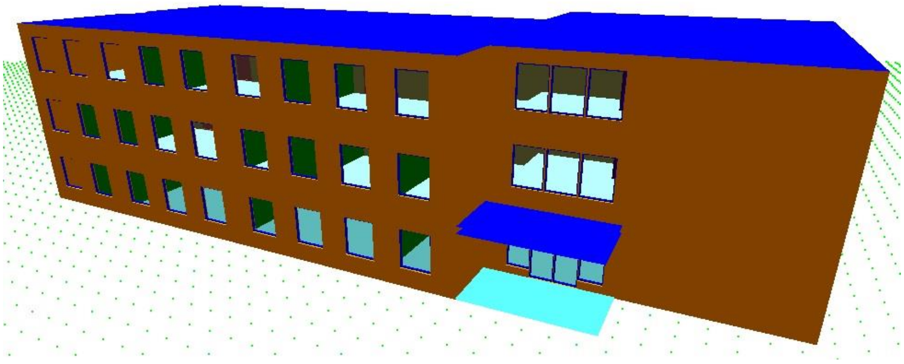

Figure 44 School B being modelled in TAS

Table 7 Thermal properties of construction elements for school B

Construction element	U-values [$Wm^{-2}K^{-1}$]
Floor to the ground	0.3
External wall (25 cm)	1.5
Internal wall (20 / 12 cm)	1.7 / 2.2
Upper floor / ceiling	0.5
Flat roof	0.2
Windows pane	5.5
Windows frame	4.5
Internal doors pane	2.0
Internal doors frame	1.8
External doors pane	5.5
External doors frame	4.5

The list of construction elements for school A and B, illustrated in Tables 6 and 7, show that some U-values of the construction elements are higher than the values allowed by the standards. In both buildings the outside walls are not insulated. The school B has single glazed windows with very high thermal conductivity.

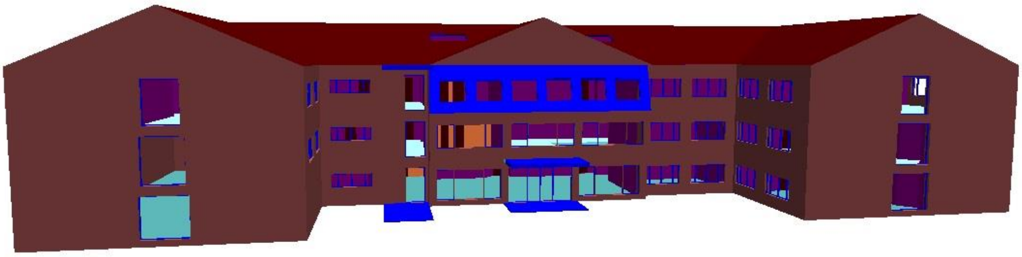

Figure 45 School C being modelled in TAS

Table 8 Thermal properties of construction elements for school C

Construction element	U-values [$Wm^{-2}K^{-1}$]
Floor to the ground	0.15
External wall (40 cm)	0.23
Internal wall (20 / 10 cm)	1.7 / 2.3
Upper floor / ceiling	0.3
Pitched roof	0.17
Windows pane	1.6
Windows frame	1.3
Internal doors pane	2.0
Internal doors frame	1.6
External doors pane	1.8
External doors frame	1.2

Table 8 illustrates the thermal properties of the construction elements for school C. The building elements have thermal conductivity according to Guideline of Energy Characteristics of Buildings from Austrian Institute of Building Technology.

More detailed building constructions of the evaluated schools are shown in Tables A-3 to A-5 (see Appendix).

2.6.4 Calibration

For calibration of the initial models of the schools A and B, a timeframe of six days in March was chosen from the monitored period, with no heating applied.

Figure 46 demonstrates the process of generating a calibrated simulation model. The initial simulation results (e.g. indoor air temperature values) are compared to the measurements, leading to a calibrated version of the simulation model. Alternative scenarios for the thermal improvement of the building can be assessed and evaluated by using a calibrated model (Mahdavi et al. 2007).

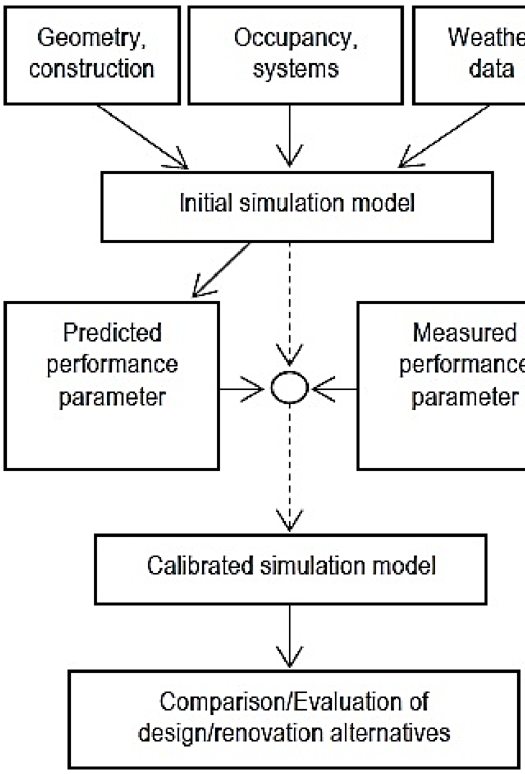

Figure 46 Illustrative depiction of the process of simulation model generation, calibration and application (Mahdavi et al. 2007)

3. Results and discussions

3.1 Measurements in school A

The mean daily indoor air temperature in monitored rooms in school A (two classrooms and an office), over the test period from February 16th to April 25th 2012, are illustrated in Figure 47 to 49 in a monthly series (February, March and April) during occupancy hours (from 08:00 to 17:00).

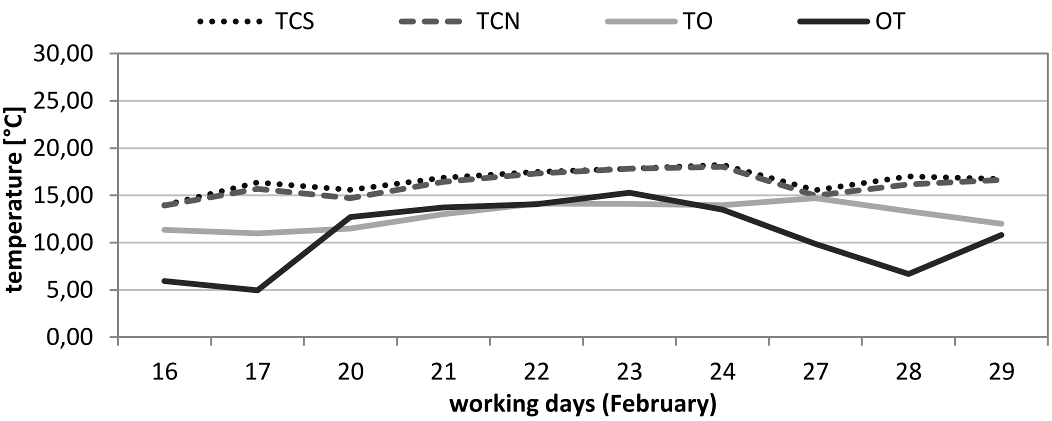

Figure 47 Mean daily indoor air temperature in selected rooms (during occupancy hours) together with outdoor temperature of Tirana in February

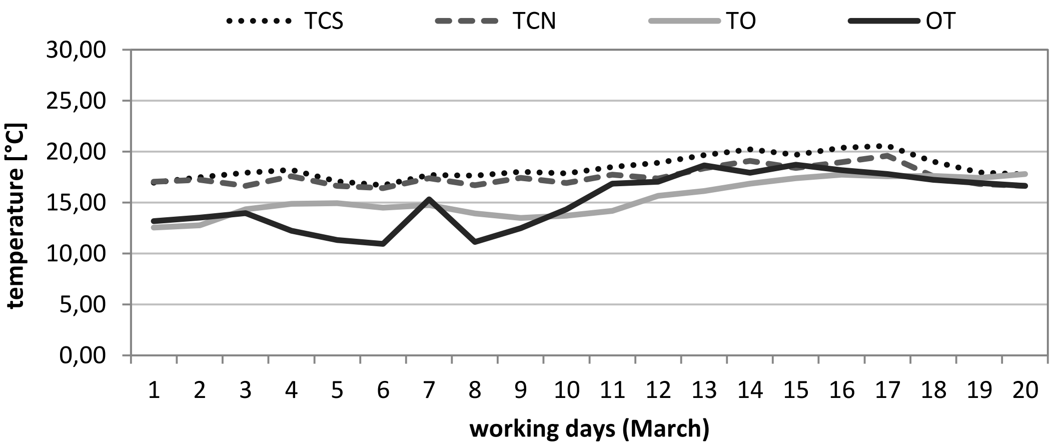

Figure 48 Mean daily indoor air temperature in selected rooms (during occupancy hours) together with outdoor temperature of Tirana in March

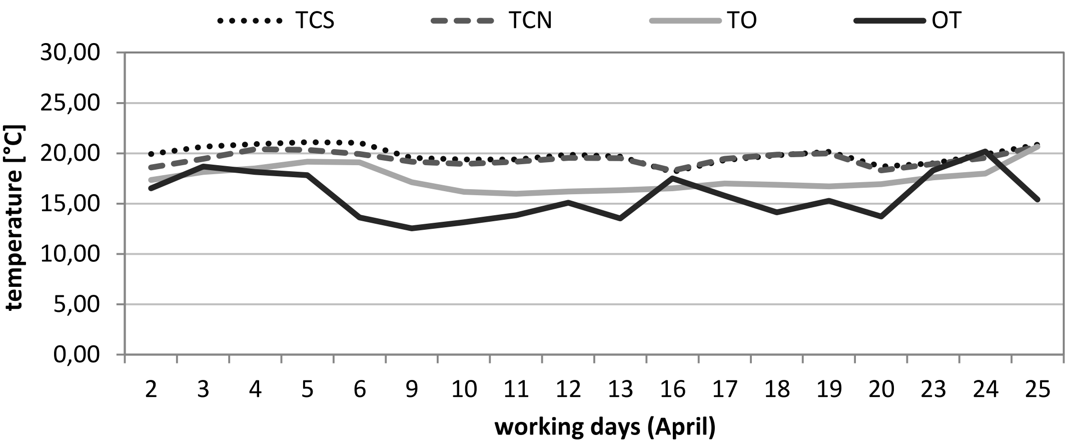

Figure 49 Mean daily indoor air temperature in selected rooms (during occupancy hours) together with outdoor temperature of Tirana in April

The monitored classrooms in school A (classroom facing south TCS and classroom facing north TCN) are occupied by the same number of students and have the same floor area, as a results they have nearly the same indoor air temperature. Though, TCS has a slightly higher internal air temperature compare to TCN, because they have different orientation. The indoor temperature for the two assessed classrooms, as displayed in Figure 47, has a tendency to remain between 15°C and 18°C over the test period in February. Figures 48 to 49 show that during March and April the indoor temperature is getting higher, because the outdoor temperature is increasing, however still they are remaining under 20°C. Based on the results there is no heating applied during the winter season in the school A.

The office (TO) has a lower indoor air temperature compared to the classrooms, especially in February, remaining under 15°C. The higher indoor temperature in the classrooms compared to the office is caused by the over occupied classroom (1.4 m² per student) whereas the office (floor area of 25m²) is occupied by one person, the deputy director.

3.2 Measurements in school B

Similar to school A, the indoor air temperature and humidity are assessed in two classrooms and in an office in school B, over the test period from February 9th to April 18th 2012. The following Graphs (Figures 50 to 52) illustrate the mean daily indoor air temperature in monitored rooms, during the occupancy hours (from 08:00 to 17:00).

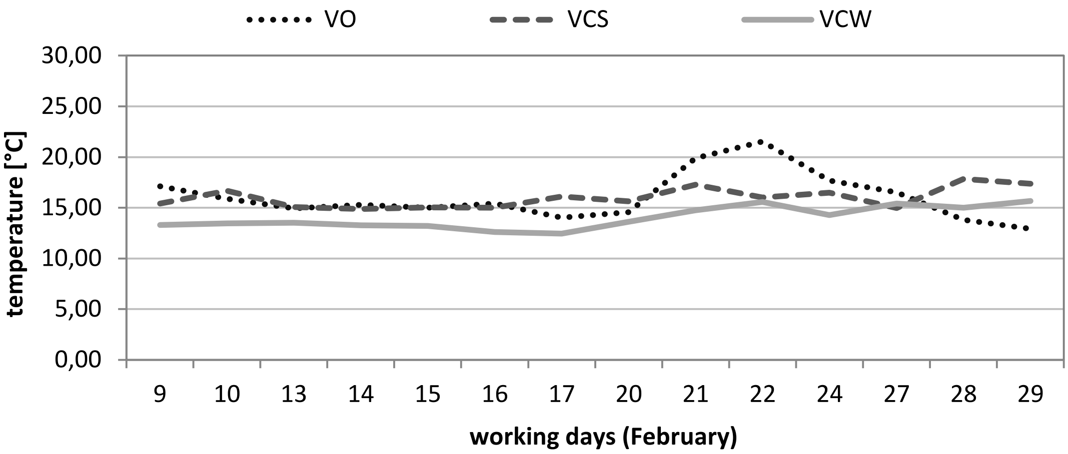

Figure 50 Mean daily indoor air temperature in selected rooms in school B (during occupancy hours) in February

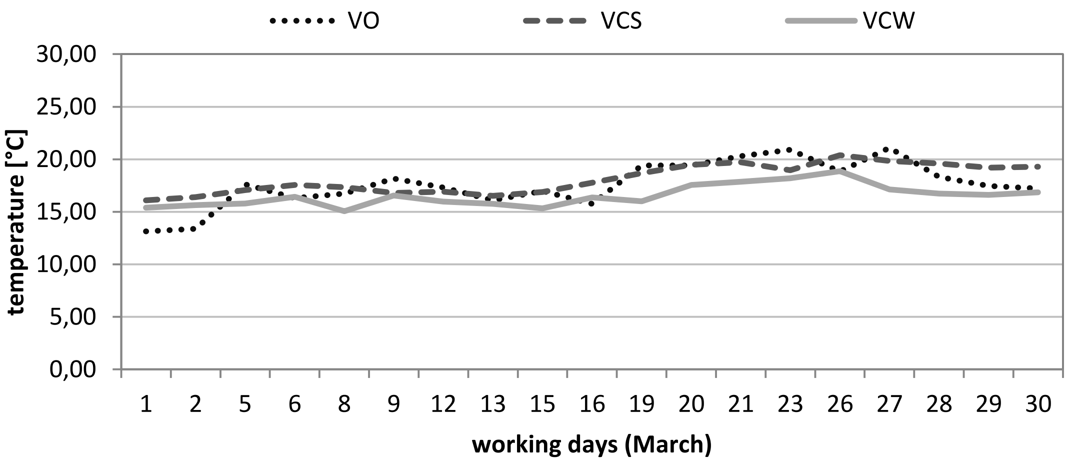

Figure 51 Mean daily indoor air temperature in selected rooms in school B (during occupancy hours) in March

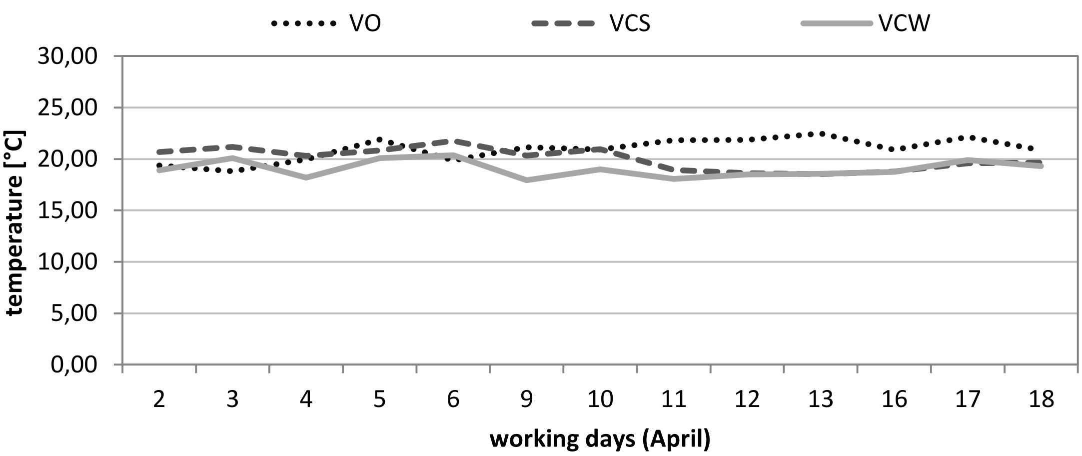

Figure 52 Mean daily indoor air temperature in selected rooms in school B (during occupancy hours) in April

The classroom facing south (VCS), in Figure 50, has almost a constant indoor air temperature from approximately 15°C to 16°C, whereas the internal temperature of the classroom facing west (VCW) ranges between 13°C and 15°C. The graphs show that classrooms do not have the same air temperature. VCS has a higher indoor temperature compare to the VCW, because they have different orientation and different floor area for the same number of students (VCS has a floor area of 38.38 m^2 whereas VCW 39.5 m^2).

The office (VO), being the principal's office, has nearly the same temperature as the classroom facing south, with the exception of three days, as displayed in Figure 50. Those days have higher temperature compare to the other evaluated rooms, from 18°C to 21°C, because some heating is applied. It is used an electrical heating device to heat the room.

The measured indoor air temperature for the observed rooms during March and April (Figure 51 and 52) varies from 16°C to 22°C, depending on the increasing of the outdoor air temperature.

3.3 Psychrometric analysis of the measurements

The combination of indoor air temperature as established by ÖNORM EN ISO 7730 and relative humidity by ÖNORM EN 13779 is illustrated in monthly psychometric analyses. The quantified thermal comfort boundary is outlined in red.

3.3.1 Psychrometric analysis - school A

The measured indoor air temperature and relative humidity of the observed rooms in school A are plotted in psychrometric charts in a monthly series (during occupancy hours). The psychrometric charts of the evaluated rooms in February are displayed in Figures 53, 54 and A-1 (see Appendix).

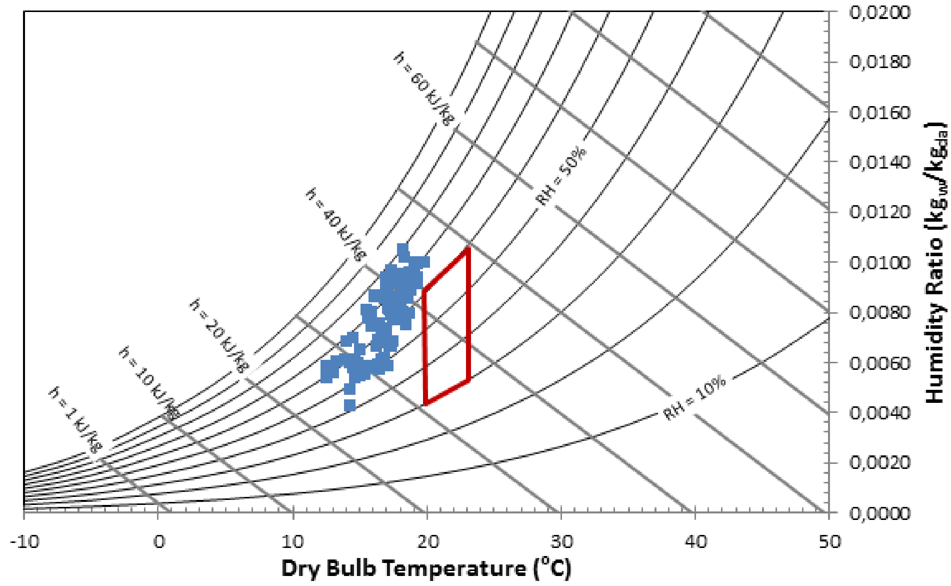

Figure 53 Mean hourly indoor air temperature and relative humidity in TCS together with thermal comfort zone, in February

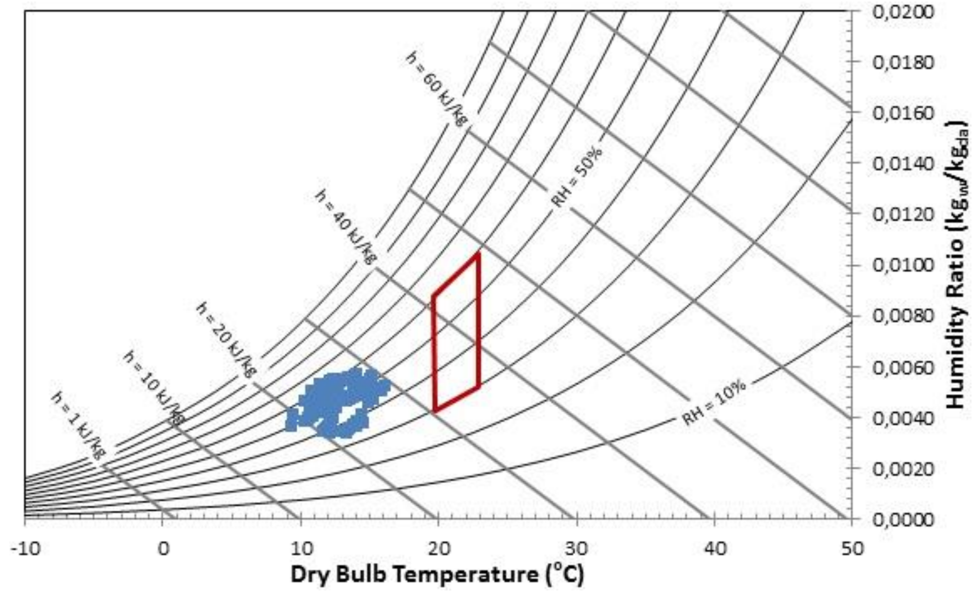

Figure 54 Mean hourly indoor air temperature and relative humidity in TO together with thermal comfort zone, in February

The internal air temperature and relative humidity during March of the assessed rooms are presented in the following Figures 55, 56 and A-2 (see Appendix).

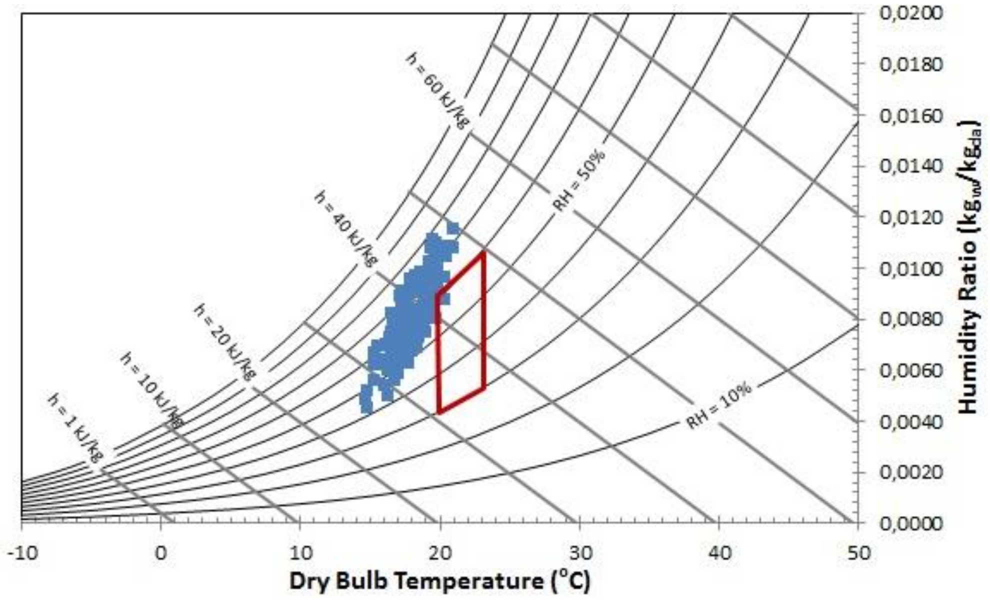

Figure 55 Mean hourly indoor air temperature and relative humidity in TCS together with thermal comfort zone, in March

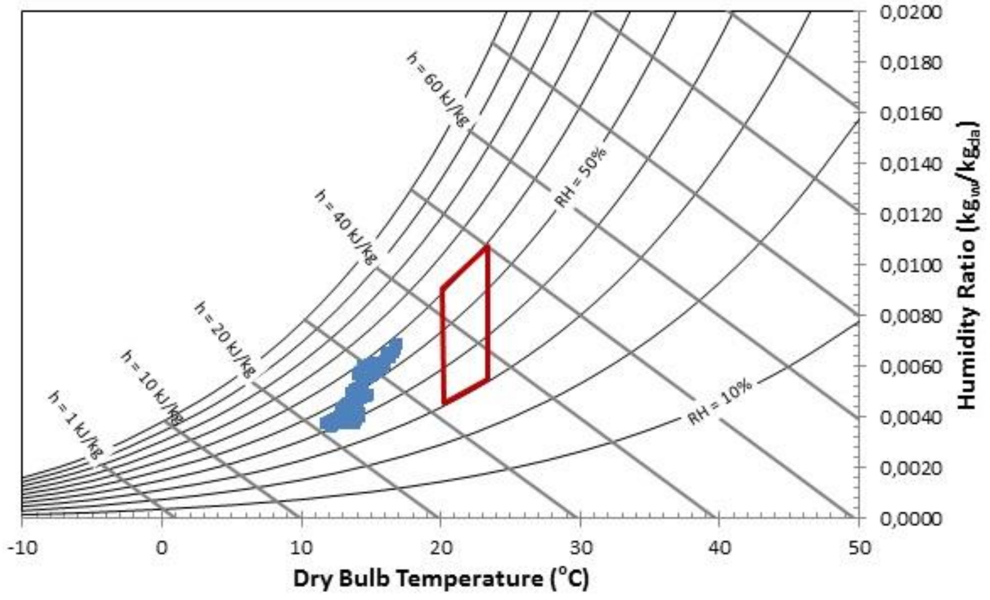

Figure 56 Mean hourly indoor air temperature and relative humidity in TO together with thermal comfort zone, in March

Figures 57, 58 and A-3 (see Appendix) show the indoor air temperature and relative humidity of the selected rooms, in April.

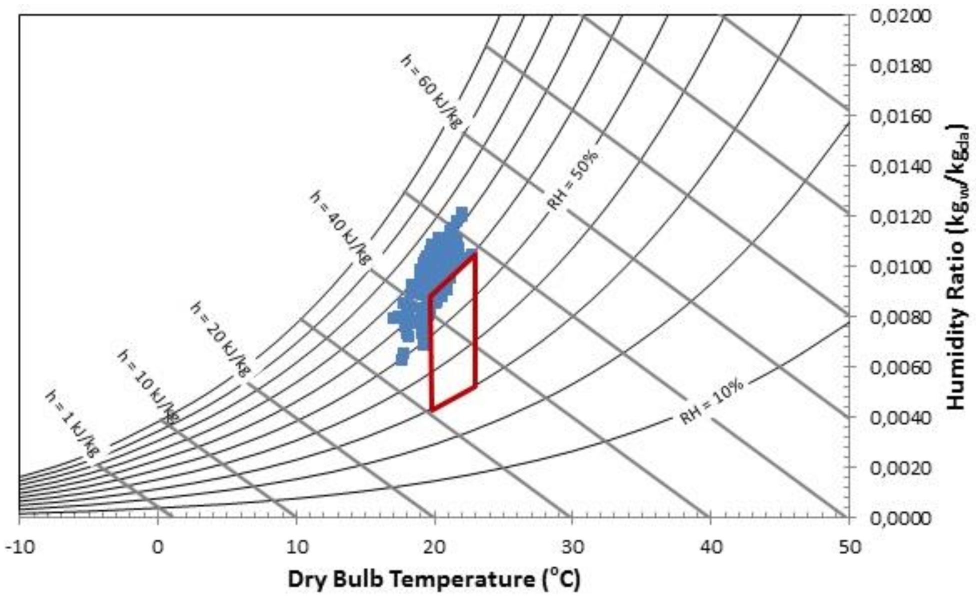

Figure 57 Mean hourly indoor air temperature and relative humidity in TCS together with thermal comfort zone, in April

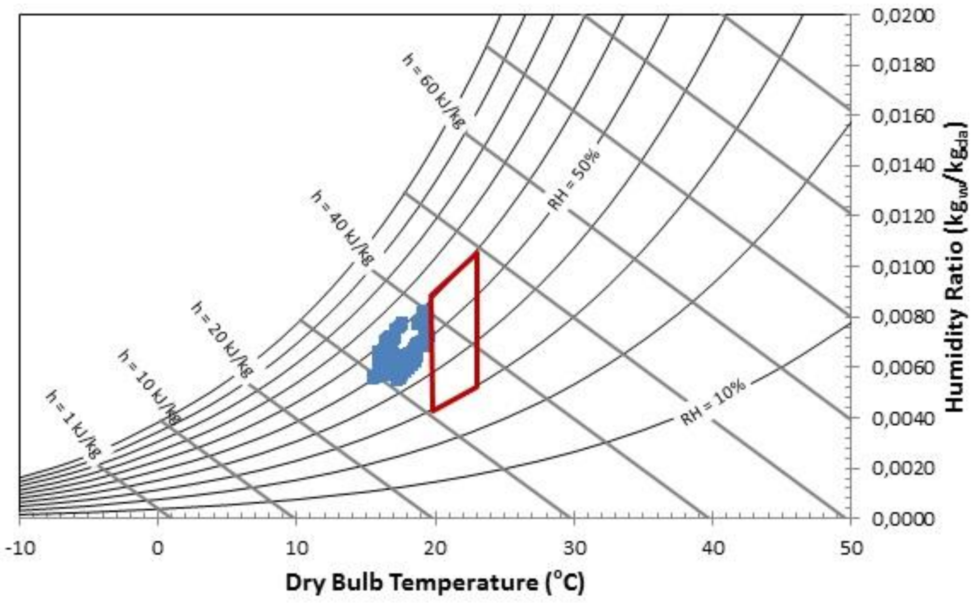

Figure 58 Mean hourly indoor air temperature and relative humidity in TO together with thermal comfort zone, in April

The inside temperature and relative humidity in school A during the whole studied period, as illustrated in the graphics above, are outside the comfort criteria as outlined by ÖNORM EN ISO.

3.3.2 Psychrometric analysis - school B

Analogous to school A, the measured indoor air temperature and relative humidity of the observed rooms in school B are plotted in psychrometric charts in a monthly series.

The psychrometric charts of the evaluated rooms in February are displayed in Figures 59, 60 and A-4 (see Appendix)

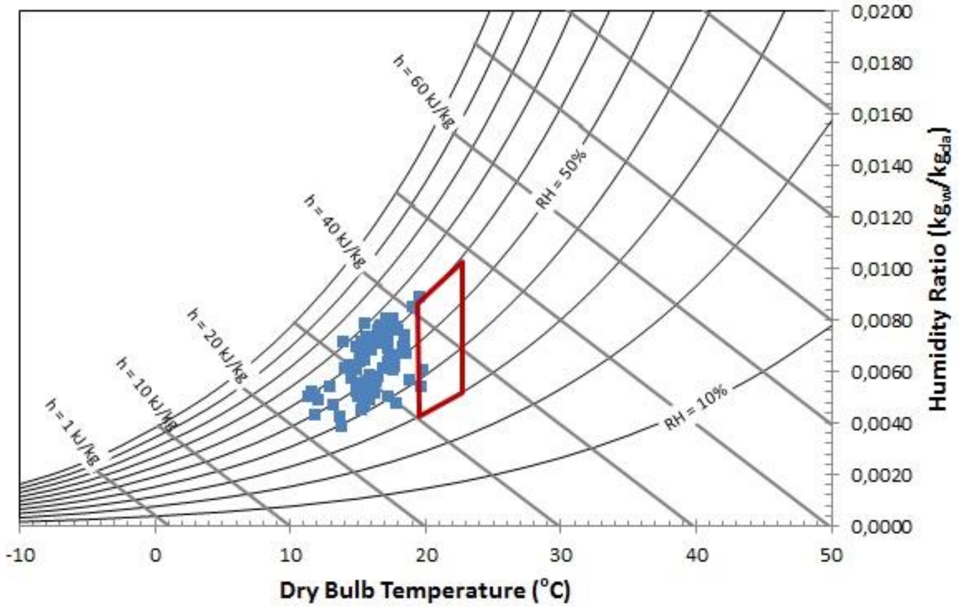

Figure 59 Mean hourly indoor air temperature and relative humidity in VCS together with thermal comfort zone, in February

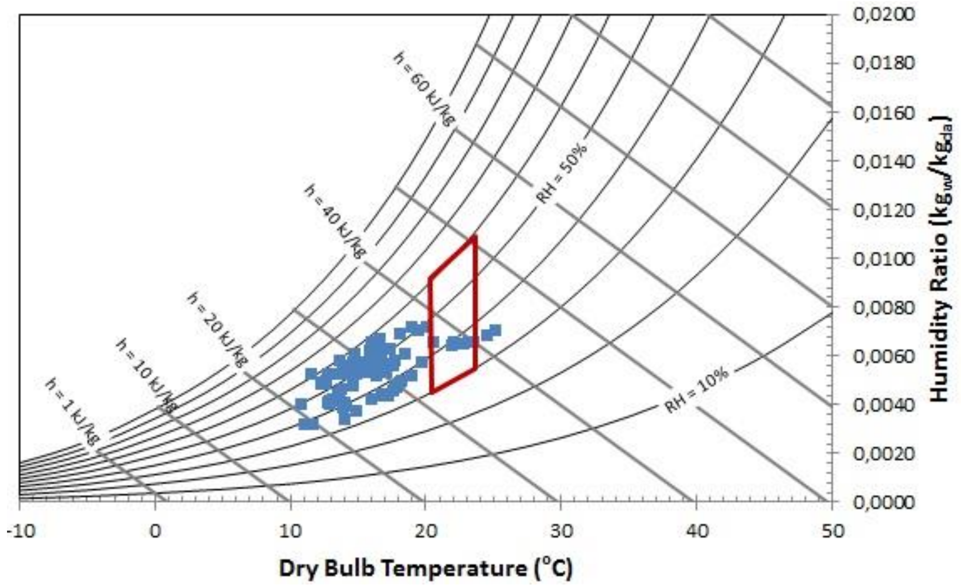

Figure 60 Mean hourly indoor air temperature and relative humidity in VO together with thermal comfort zone, in February

Indoor air temperature and relative humidity in March of the selected rooms are illustrated in figures 61, 62 and A-5 (see Appendix).

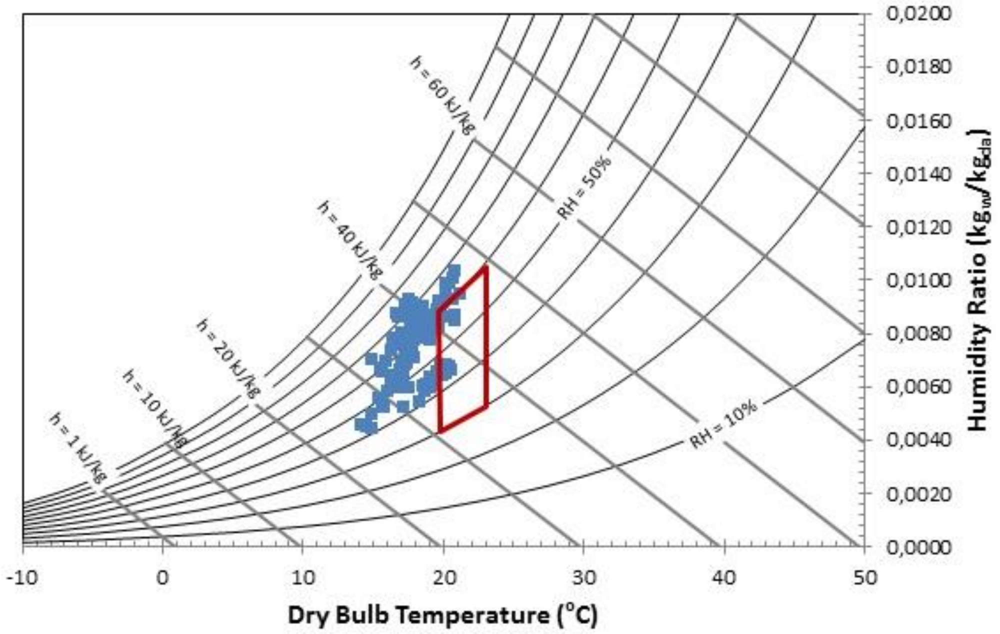

Figure 61 Mean hourly indoor air temperature and relative humidity in VCS together with thermal comfort zone, in March

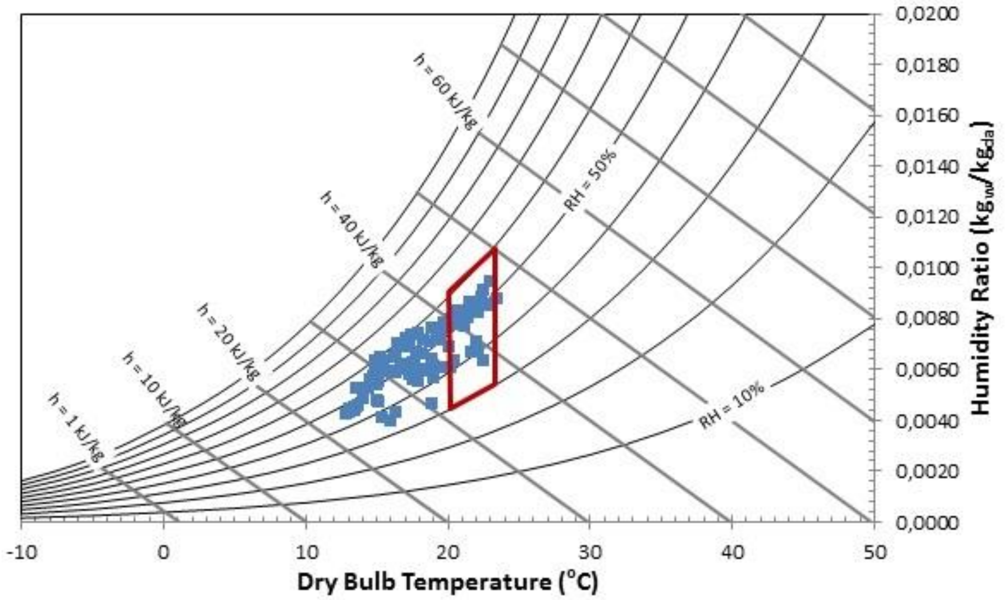

Figure 62 Mean hourly indoor air temperature and relative humidity in VO together with thermal comfort zone, in March

Figures 63, 64 and A-6 (see Appendix) display the indoor air temperature and relative humidity of the observed rooms in April.

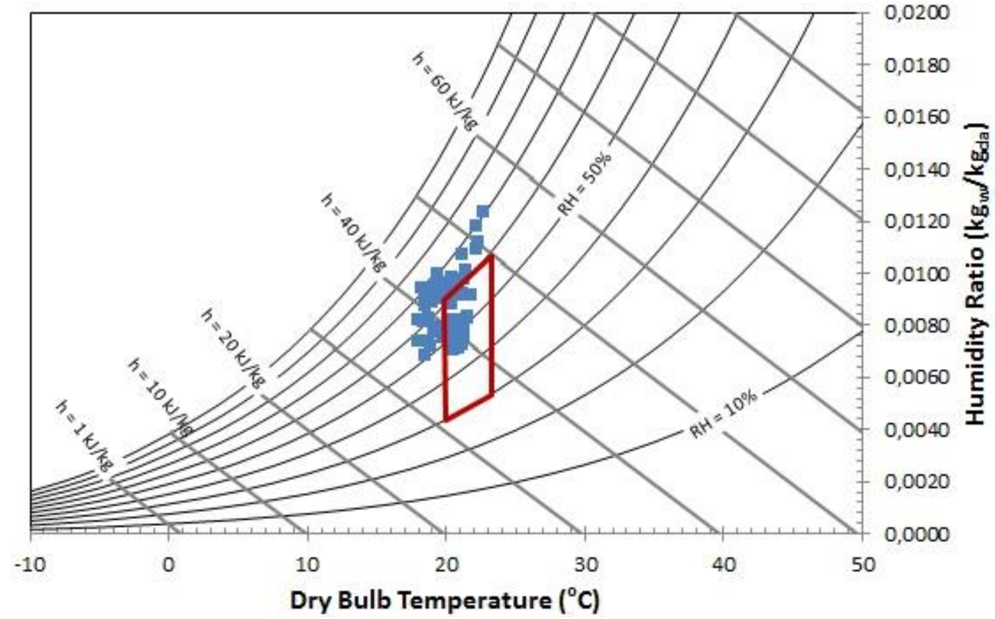

Figure 63 Mean hourly indoor air temperature and relative humidity values in VCS together with thermal comfort zone, in April

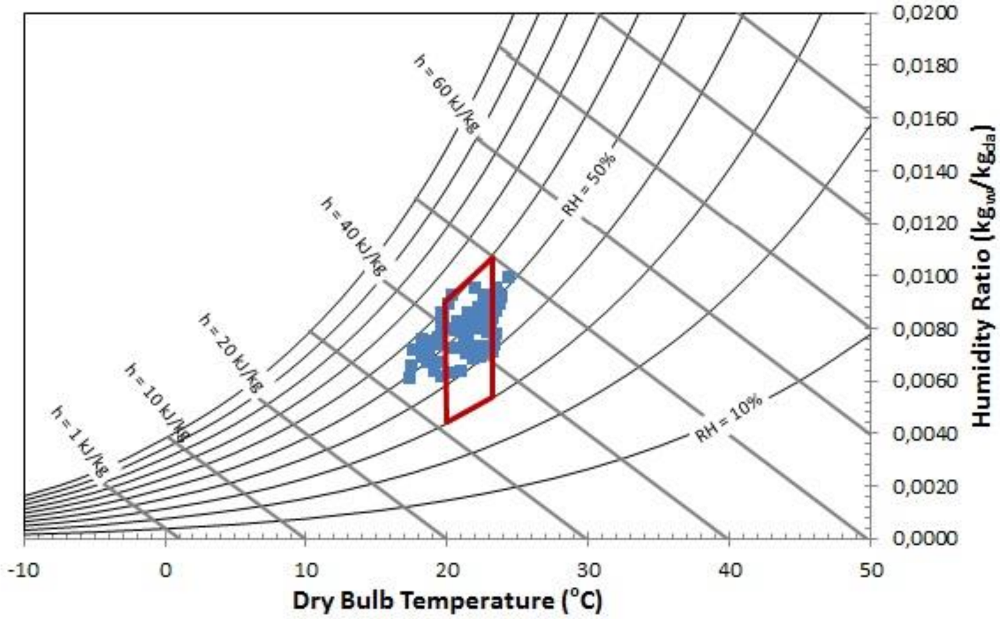

Figure 64 Mean hourly indoor air temperature and relative humidity values in VO together with thermal comfort zone, in April

School B compare to A, has a higher compliance with ÖNORM EN ISO criteria, especially the office, as some heating is applied. Still most of the time during the studied period, the indoor air temperature and relative humidity are outside the comfort criteria. During April, as shown in Figure 64, the internal air temperature and relative humidity values are approximately 75% of the time within the acceptable boundaries of comfort, as the outdoor air temperature is increasing.

3.4 Calibration

3.4.1 Calibration - school A

The initial simulation model is generated based on the collected data regarding the morphology of the building, internal gains, calendar, ventilation, weather data, orientation and altitude.

A period of six days is chosen to calibrate the initial model. The collected data for internal gains (light, equipment and occupancy) and ventilation are based on the occupancy data, with no heating applied. Table 9 shows the input assumption for the internal gains and the ventilation regime to generate the initial simulation model. It is assumed ventilation regime of 2 ACH during the occupancy hours for the classrooms, because the students were complaining about the not sufficient natural ventilation. During unoccupied hours is assumed a ventilation regime of 0.4 ACH, because the building is an old one and has potential for air leakage.

Table 9 Internal gains and ventilation regime to generate the initial simulation model of school A

Zone	Internal gains [Wm^{-2}]	Ventilation regime [ACH]
Classroom	39	2.0 – 0.4
Office	5.8	1.0 – 0.4

Internal gains for the classrooms

- *Lighting gain - 2 Wm^{-2}*
- *Occupancy sensible gain - 30 Wm^{-2}*
- *Occupancy latent gain - 7 Wm^{-2}*
- *Occupancy hours - 8:00 - 17:00*

Internal gains for the office

- *Lighting gain - 1.0 Wm^{-2}*
- *Occupancy sensible gain - 2.8 Wm^{-2}*
- *Occupancy latent gain - 0.6 Wm^{-2}*
- *Equipment sensible gain - 1.0 Wm^{-2}*
- *Equipment latent gain - 0.25 Wm^{-2}*
- *Occupancy hours - 8:00 - 13:00*

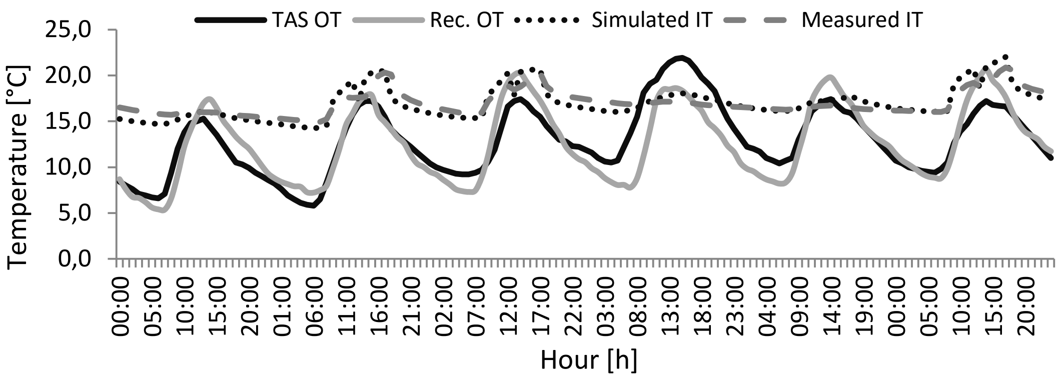

Figure 65 Comparison predicted and measured air temperature in TCS, over a period of 6 days in March 2012 (initial simulation model)

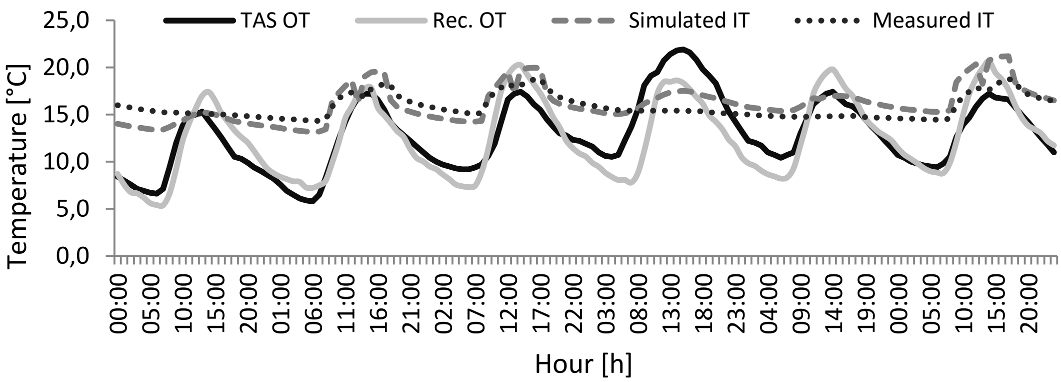

Figure 66 Comparison predicted and measured air temperature in TCN, over a period of 6 days in March 2012 (initial simulation model)

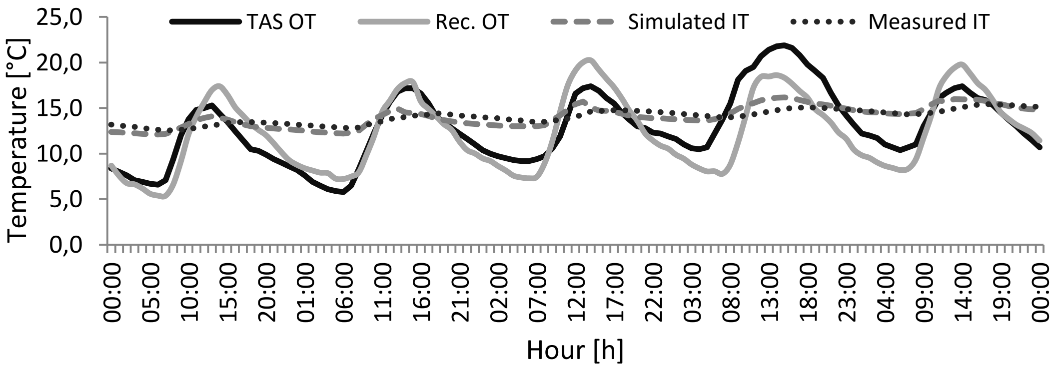

Figure 67 Comparison predicted and measured air temperature in TO, over a period of 6 days in March 2012 (initial simulation model)

As illustrated in Figures above, from 65 to 67, the comparison predicted and measured air temperature (IT – indoor temperature, OT – outdoor temperature) in the assessed rooms show significant difference. Consequently this input assumption of internal gains and ventilation regime are not accurate.

To build a calibrated model, based on the comparison of the predicted results of the initial model regarding internal air temperature, is used the internal gains and a ventilation regime as shown in Table 10. Figures 68 to 70 display the calibrated model.

Table 10 Internal gains and the ventilation regime to build a calibrated model of school A

Zone	Internal gains [Wm^{-2}]	Ventilation regime [ACH]
Classroom	33	3.0 – 0.3
Office	5.8	1.0 – 0.3

Internal gains for the classrooms

- *Lighting gain - 2 Wm^{-2}*
- *Occupancy sensible gain - 25 Wm^{-2}*
- *Occupancy latent gain - 6 Wm^{-2}*

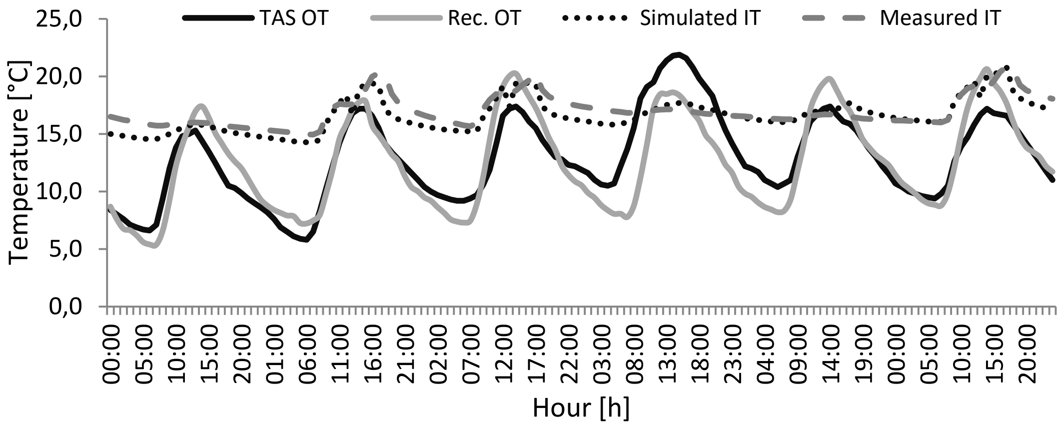

Figure 68 Comparison predicted and measured air temperature in TCS, over a period of 6 days in March 2012 (calibrated model)

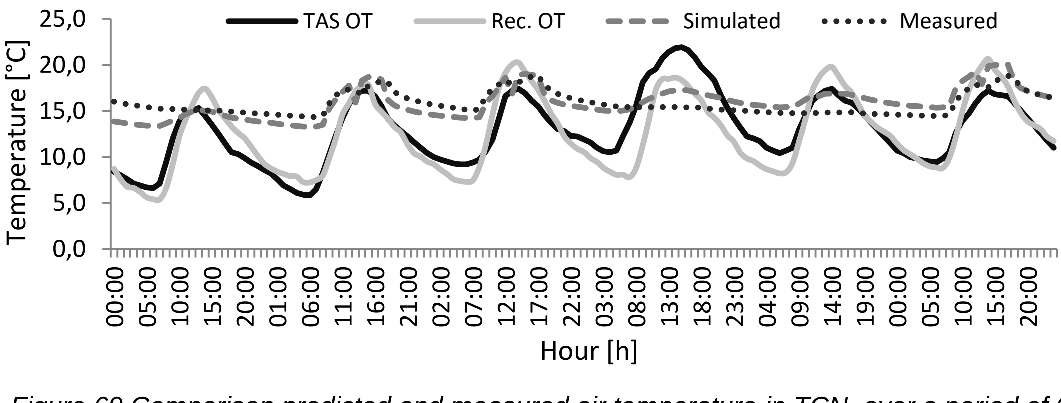

Figure 69 Comparison predicted and measured air temperature in TCN, over a period of 6 days in March 2012 (calibrated model)

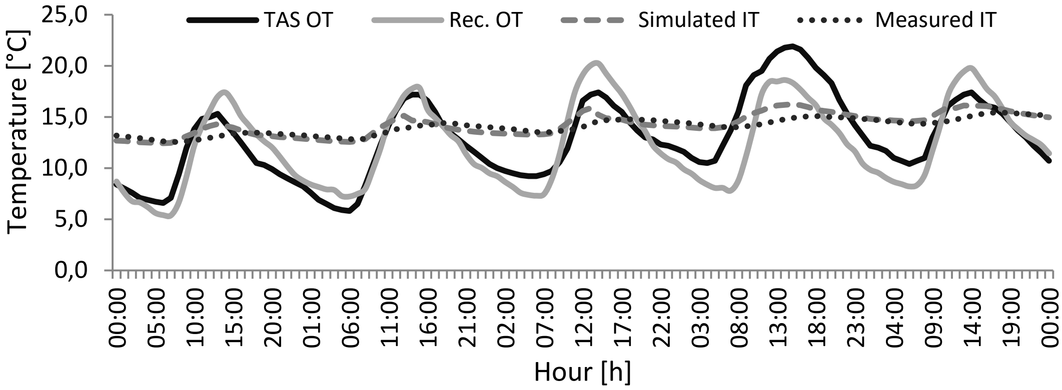

Figure 70 Comparison predicted and measured air temperature in TO, over a period of 6 days in March 2012 (calibrated model)

3.4.2 Calibration - school B

To generate the initial simulation model is based on the collected data regarding the morphology of the building, internal gains, calendar, ventilation, weather data, orientation and altitude.

The input assumption for internal gains (light, equipment and occupancy) and ventilation regime, for calibrating the initial simulation model are illustrated in Table 11. Internal gains and ventilation regime are similar to the school A, because both schools have similar schedule and occupancy data. Figures 71 – 73 display the calibrated model.

Table 11 Internal gains and the ventilation regime to build a calibrated model of school B

Zone	Internal gains [Wm^{-2}]	Ventilation regime [ACH]
Classroom	33	3.0 – 0.3
Office	5.8	1.0 – 0.3

Internal gains for the classrooms

- *Lighting gain - 2 Wm^{-2}*
- *Occupancy sensible gain - 25 Wm^{-2}*
- *Occupancy latent gain - 6 Wm^{-2}*
- *Occupancy hours - 8:00 - 13:00*

Internal gains for the office

- *Lighting gain - 1.0 Wm^{-2}*
- *Occupancy sensible gain - 2.8 Wm^{-2}*
- *Occupancy latent gain - 0.6 Wm^{-2}*

- *Equipment sensible gain - 1.0 Wm^{-2}*
- *Equipment latent gain - 0.25 Wm^{-2}*
- *Occupancy hours - 8:00 - 13:00*

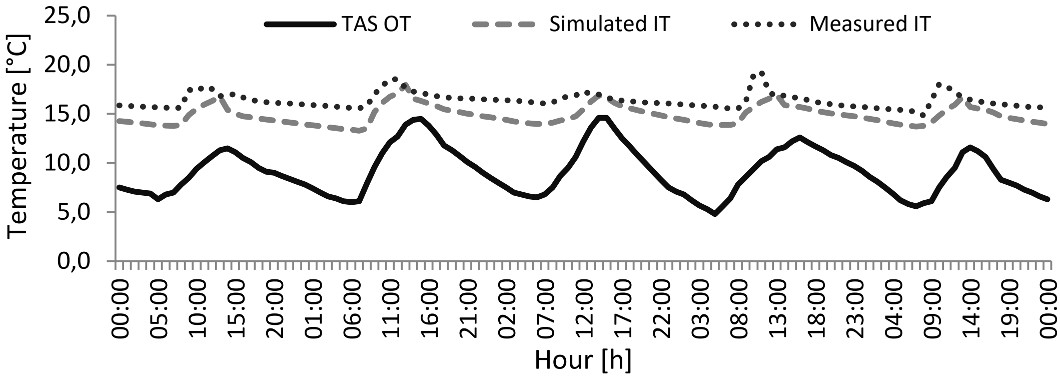

Figure 71 Comparison predicted and measured air temperature in VCS, over a period of 6 days in March 2012 (calibrated model)

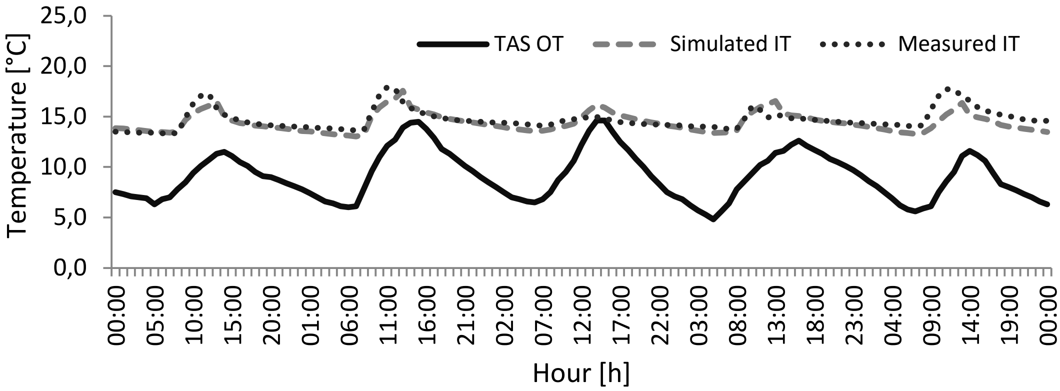

Figure 72 Comparison predicted and measured air temperature in VCW, over a period of 6 days in March 2012 (calibrated model)

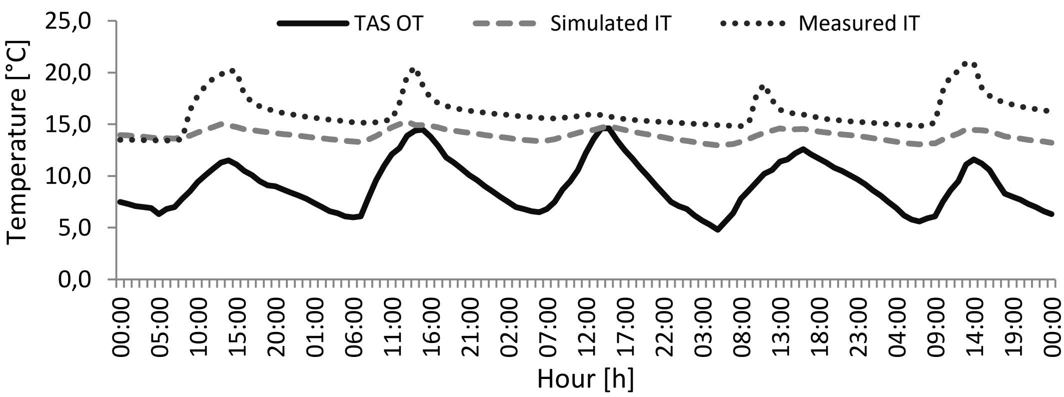

Figure 73 Comparison predicted and measured air temperature in VO, over a period of 6 days in March 2012 (calibrated model)

3.5 Simulation

During the simulation, a schedule is applied which allows the heating to turn on when the temperature during the occupying hours drops below a certain limit. The indoor temperature of the classrooms and administration's rooms is set to 20 °C, whereas at all the working places and the auxiliary rooms the temperature is set up to 18 °C.

The biggest heating loads, as expected, were recorded in January and December, when the heating season is at its peak, and the external air temperatures are the lowest.

3.5.1 Simulation – school A

The energy demand for heating school A reached 41183 $kWha^{-1}$ with 19.1 $kWhm^{-2}a^{-1}$ (netto). Figure 74 illustrates the monthly energy demand.

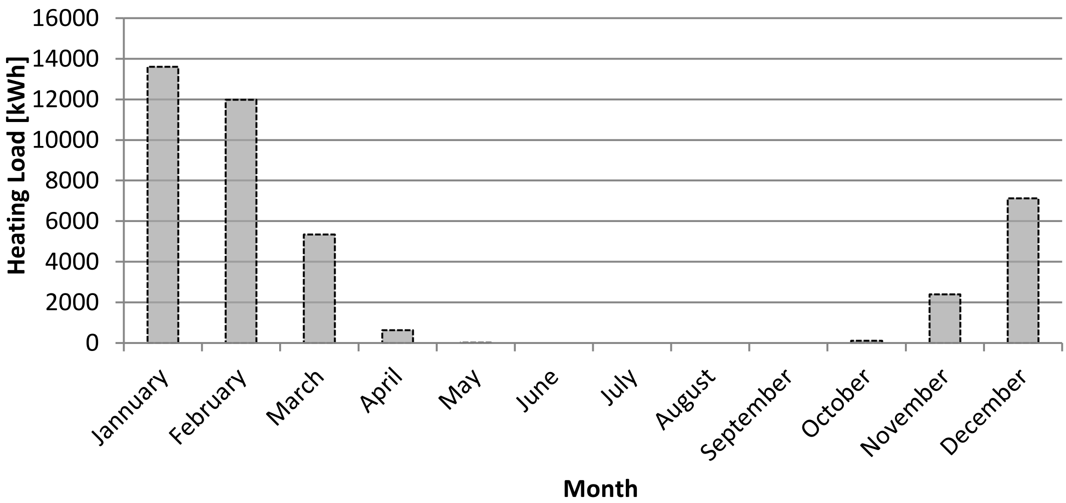

Figure 74 Monthly heating load distribution for the existing situation of school A

An improvement is proposed based on six scenarios. Thermal insulation with different thickness and different properties (lambda) is applied on the outside walls (Table 12). After meeting the standards for conduction values, the annual heating demands for the six scenarios for school A, displayed in Figure 75, dropped to almost half.

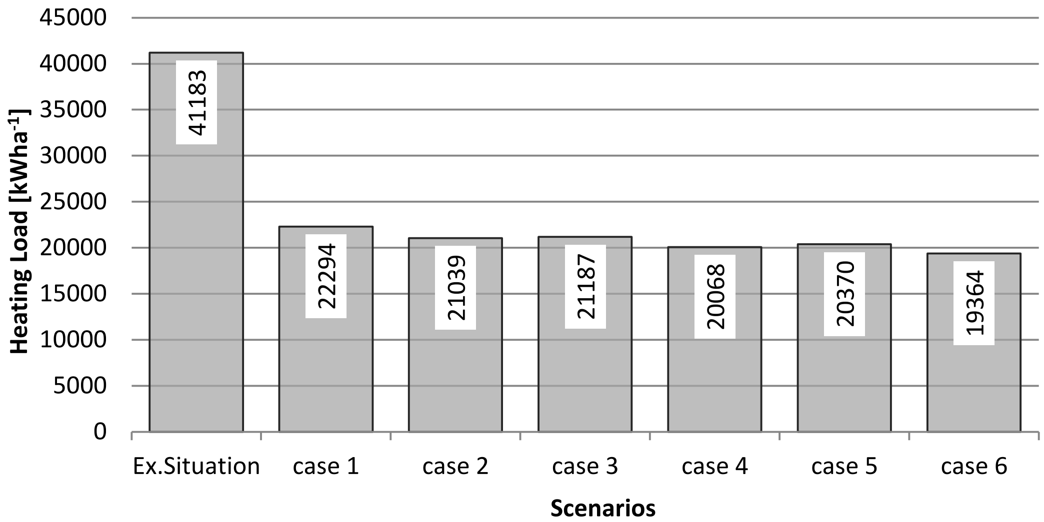

Figure 75 Annual heating demand - scenarios (school A)

Table 12 Thickness and properties of the thermal insulation for the scenarios - school A

Scenarios	**Improvement [%]**
1) Insulation d=8 cm, λ=0.04 $Wm^{-1}K^{-1}$	45.9
2) Insulation d=8 cm, λ=0.031 $Wm^{-1}K^{-1}$	48.9
3) Insulation d=10 cm, λ=0.04 $Wm^{-1}K^{-1}$	48.6
4) Insulation d=10 cm, λ=0.031 $Wm^{-1}K^{-1}$	51.3
5) Insulation d=12 cm, λ=0.04 $Wm^{-1}K^{-1}$	50.5
6) Insulation d=12 cm, λ=0.031 $Wm^{-1}K^{-1}$	53.0

Heating demand in the six scenarios, based on dynamic thermal simulations, indicated significant decrease. Nevertheless the existing building has relatively low heating demand of 19.1 $kWhm^{-2}a^{-1}$, although there is no thermal insulation applied. However, measured indoor environmental parameters display indoor temperatures below the comfort ranges. Hence, both thermal insulation and adapted heating operation have to be considered as improvement measures.

3.5.2 Simulation – school B

The total energy demand for heating school B, based on dynamic thermal simulations, is 14903 $kWha^{-1}$ where the value per square meter (netto) is 10.1 $kWhm^{-2}a^{-1}$. The monthly energy demand is shown in Figure 76.

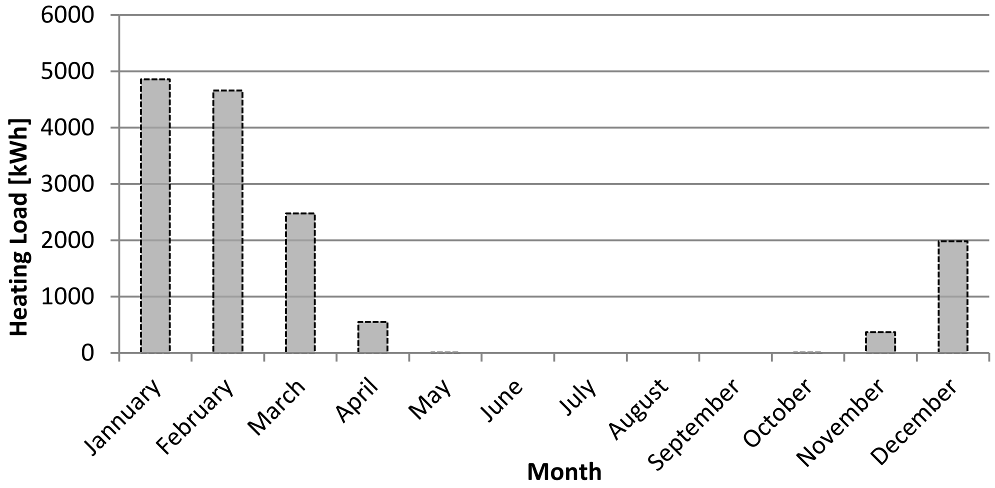

Figure 76 Monthly heating load distribution for the existing situation of school B

Similar to school A, an improvement is proposed for school B based on eight scenarios. Thermal insulation is applied on the outside walls with different thickness and different properties (lambda) and changed to windows to better thermal properties, illustrated in Table 13. Figure 77 show the annual heating energy demand for all the scenarios. Heating loads for school B after the improvements dropped to almost 80%, starting from the scenario three to eight.

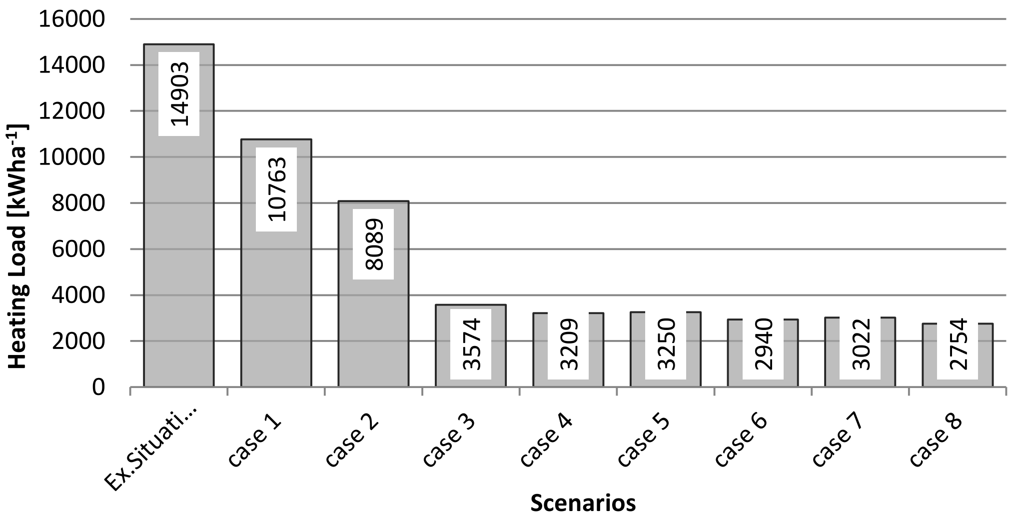

Figure 77 Annual heating demand - scenarios (school B)

Table 13 Thickness and properties of the thermal insulation for the scenarios - school B

Scenarios	Improvement [%]
1) Replacing old windows with double glazed windows U=1.7 $Wm^{-1}K^{-1}$	27.8
2) Insulation d=8 cm, λ=0.04 $Wm^{-1}K^{-1}$ (without windows improvement)	45.7
3) Insulation d=8 cm, λ=0.04 $Wm^{-1}K^{-1}$ (with windows improvement)	76.0
4) Insulation d=8 cm, λ=0.031 $Wm^{-1}K^{-1}$	78.5
5) Insulation d=10 cm, λ=0.04 $Wm^{-1}K^{-1}$	78.2
6) Insulation d=10 cm, λ=0.031 $Wm^{-1}K^{-1}$	80.3
7) Insulation d=12 cm, λ=0.04 $Wm^{-1}K^{-1}$	79.7
8) Insulation d=12 cm, λ=0.031 $Wm^{-1}K^{-1}$	81.5

The heating demand for school B without improvements (10.1 $kWhm^{-2}a^{-1}$) is lower than the heating demand for school A (19.1 $kWhm^{-2}a^{-1}$). Analogue to school A, thermal insulation, changing to windows to better properties and adapted heating operation have to be considered as improvement measures for school B.

3.5.3 Simulation – school C

The energy demand for heating school C is 66307$kWha^{-1}$ and per square meter (netto) is 18.8 $kWhm^{-2}a^{-1}$. The value per square meter is close to the energy demand of school A, although the building elements of school C have better thermal conductivity, because Peshkopi has colder climate compared to Tirana. Figure 78 shows monthly energy demand for school C.

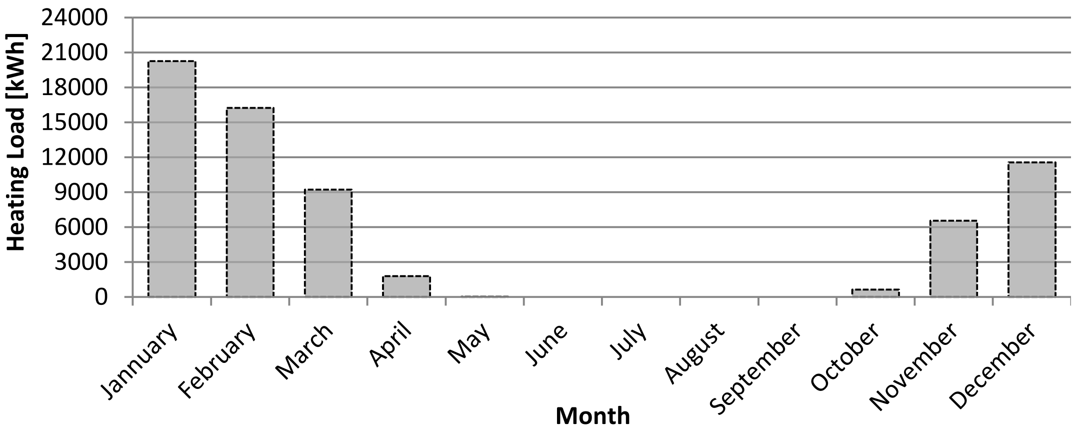

Figure 78 Monthly heating load for school C

School B has the lowest energy heating demand compared to the other assessed schools, although it has the poorest thermal conductivity of the construction elements. Figure 79 shows the significant difference of the climate conditions of the selected cities. Peshkopi has the coldest climate from approximately 6°C compared to Tirana and approximately 12°C compared to Vlora during the winter season (Meteotest 2012).

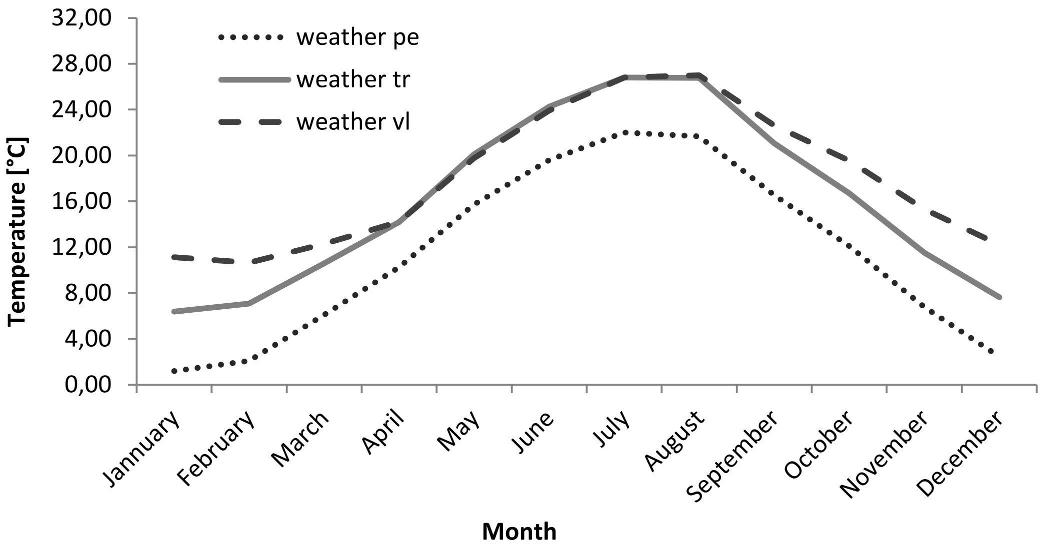

Figure 79 Mean monthly outdoor temperature of the three selected cities, during the year 2012 (Meteotest 2012)

To illustrate the importance of the climate conditions in relation to the energy heating demand, the annual heating demand per square meter (netto) for school C is computed based on three scenarios (Table 14). The heating load (HL) for school C is calculated with the weather file of Peshkopi (W-PE), weather file of Tirana (W-TR) and Vlora (W-VL). Figure 80 illustrates the comparison of the annual heating demands for school C according to the three climate zones.

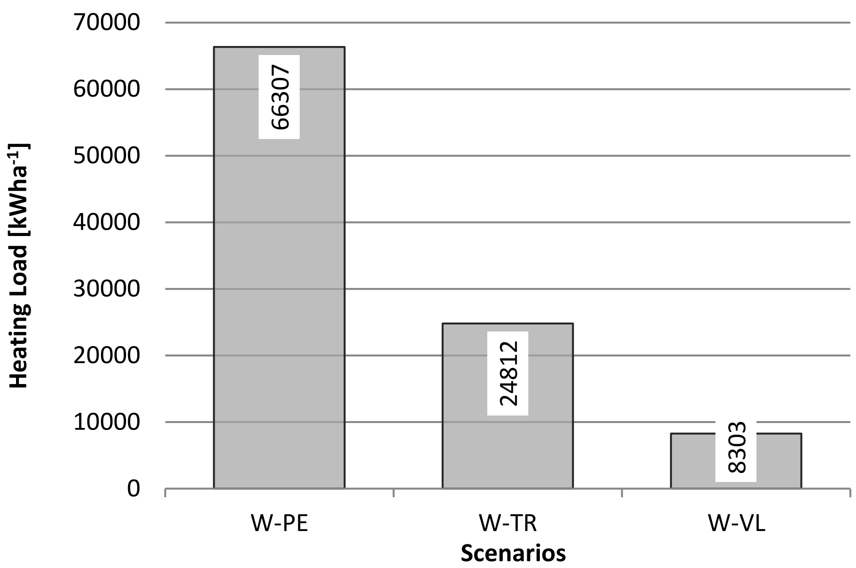

Figure 80 Comparison predicted annual heating load for school C computed with the weather files of the selected cities

Table 14 Scenarios of the heating loads for school C computed with the weather files of the selected cities

Heating loads (HL) for school C - scenarios	**HL per square meter (netto) [kWhm^{-2}a^{-1}]**
HL computed with the W-PE	18.8
HL computed with the W-TR	7.0
HL computed with the W-VL	2.4

HL for school C computed with W-TR is approximately three times lower than HL calculated with W-PE, whereas HL computed with W-VL is almost eight times lower. This evaluation shows that school A and B have relatively low heating demand, because these cities have warm climate conditions, especially Vlora, although they are not thermal insulated.

The occupancy data has a major impact in the heating load, because the assessed buildings are heating during the operating time, from 8:00 to 17:00, excluding weekends and official holidays. Additional simulations are made to illustrate this impact, see Appendix.

4. Conclusions

This study focuses on the thermal performance of three school buildings in Albania in view of energy demand and indoor thermal comfort. One-site data monitoring and numeric thermal simulation were deployed to evaluate the thermal performance of the examined buildings.

The monitored data, indoor air temperature and relative humidity (during 10 weeks of observation) resulted that the two assessed schools do not meet the comfortable environment criteria according to the European and Albanian Standards. The recorded internal air temperature in the examined classrooms during February and March, in the school in Tirana (school A) and in Vlora (school B), has a tendency to remain between approximately 15°C and 18°C. Psychometric charts of school A indicated that this building does not meet the acceptable temperature and relative humidity parameters of the standard, as no heating is applied. School B, in comparison to school A, has a higher compliance with ÖNORM EN ISO criteria, because in the examined office some heating is applied. However most of the times during the studied period, the temperature and relative humidity for the selected rooms are outside the comfort criteria.

A calibrated model is built in order to identify measures for decreasing the heating load of the examined school buildings. An improvement is proposed for both schools, by adding insulation on the walls or changing to windows to better properties. On one hand the results display significant decreasing of the heating demand after the improvements for both schools. On the other hand the existing situation of the assessed (not-insulated) buildings already show rather low heating demand, 19.1 $kWhm^{-2}a^{-1}$ for school A and 10.1 $kWhm^{-2}a^{-1}$ for the school B. However, these status quo results should be contrasted with both the climatic conditions within the corresponding regions. To reach a better thermal performance of these buildings and to increase the thermal comfort for teachers and students in Albania, careful consideration of the influencing parameters should be performed. Based on these considerations, retrofit strategies can be designed and applied, such as a comprehensive thermal insulation and adapted heating devices.

School building in Peshkopi (school C) was still undergoing construction during the monitoring period and therefore was not subjected to monitoring**.** This building is analysed based on the energy simulation. School C showed a rather good performance, which seems compliant to European and Albanian standards.

4.1 Future research

A relevant research on the indoor air quality, by measuring the indoor carbon dioxide levels with a carbon dioxide monitor would be more enlightening. Classrooms have one of the highest densities of all occupation types, thus the main sources of the indoor pollution in the school buildings are the students and teachers occupying them. Therefore it would be beneficial to observe the ventilation regime and the occupant’s behaviour as well, as these internal conditions can affect the simulations results.

5. References

Albania Energy Efficiency Centre 2007 (EEC). *The energy in Albania (newsletter).* Retrieved 20 Oktober, 2016, from: *http://www.eec.org.al*

ANSI / ASHRAE 55 2004. *Thermal Environmental Conditions for Human Occupancy.* USA Retrieved 10 December 2016, from: *https://www.ashrae.org ,* pp. 4

ASHRAE 2011. *Advanced Energy Design Guide for K-12 School Buildings (Achieving 50% Energy Savings Toward a Net Zero Energy Building).* USA, pp. xv.
Retrieved 20 December, 2016, from: *https://www.ashrae.org*

Bruci, E. 2008. *Climate variability and trends in Albania. IWE, Tirana Polytechnic University*. Tirana, Albania.

CENSUS-AL 2011. *Censusi i Popullsise dhe i Banesave ne Shqiperi, rezultatet paraprake (Preliminary Results of the Population and Housing Census).* Tirane, Albania: Media print (December). Retrieved 20 November 2016, from: *http://instat.gov.at*

Decision of Council of Ministers (DCM) No.38 2003. Law No. 8937, 12 September. "*Energy Saving on Buildings*" item 5.

EDSL TAS 2016, TAS version 9.3.3 Environmental Design Solutions Limited. Retrieved 2 December 2016, *from: www.edsl.net*

Exergia Consulting Team 2008. *Final Feasibility Study for Introducing Energy Efficiency Measures at Development Center 'Pellumbat'*, Tirana. Athens, June 2008, pp. 20 Retrieved 15 January 2017, from: *http://exergia.gr/projects/energy/energy-efficiency*

Google 2017. *Google Maps*. Retrieved 15 February 2017, from: *https://www.google.at/maps*

IHM 1978, *Albania Climate Institute of Hydro Meteorology*, Tirana 1978

IHM 2006, Albania Climate Institute of Hydro Meteorology, Tirana 2006. Quoted in Co PLAN, 2007. *Study on Assessment of renewable energy sources potentials in Albania, Institute for Habitat Development.* Tirana, Albania. Retrieved 25 December 2016, from: *http://pdc.ceu.hu*

INSTAT (Instituti i Statistikave) 2010. *Shqiperia ne Shifra (Albania in Figures)*. Tirane, Albania, 2010. Retrieved 15 January 2017, from: *http://www.instat.gov.al*

INSTAT 2011. *Censusi i Popullsise dhe i Banesave (Population and Housing Census).* Tirane, Albania: Adel Print (2012). Retrieved 2 February 2017, from: *http://www.instat.gov.al*

INSTAT 2017, 1 January. *Population of Albania.* Tirane, Albania. Retrieved 20 February 2017, from *http://www.instat.gov.al*

ISO 7730, third edition 2005, 15 November. *Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.* Retrieved 30 February 2017, from *http://www.iso.org*

Mahdavi A, Orehounig K., Mikats N., Lambeva L., El Habashi A. 2007. *Analyzing Traditional Buildings Via Empirically Calibrated Building Performance Models.* Proceedings of the 10th International Building Performance Simulation Association Conference and Exhibition, Beijing: China.

Meteotest 2012, *Meteonorm Version 6.1.* Retrieved January 20, 2016, from: *www.meteonorm.com*.

Ministria e Arsimit dhe Shkences 2007, Qershor. *Projekt Detyre Ndertim shkolle ne Peshkopi.* Albania

Ministry of Education and Science 2002*. Architectural/Engineering service to elaborate building material specifications and school furniture specification.* Volume 1, norms and design specifications. Tirana, Albania.

Ministry of Environment, Forest and Water Administration 2005 (MOEFWA), December. *Albania's Technology needs Assessment.* Tirana, Albania: Publishing and printing house "ILAR". Retrieved 5 December 2016, from*: www.ccalb.org* or *www.unfccc.int*, pp. 119-120

Mustaqi, V., Sanxhaku, M. 2006. Identification of the zones with enough energy potential for application of the RET in Albania, in the framework of Sustainable Energy for Albania. Quoted in Co PLAN, 2007. *Study on Assessment of renewable energy sources potentials in Albania, Institute for Habitat Development.* Tirana.
Retrieved December 25, 2016, from: *http://pdc.ceu.hu*

OIB - RICHTLINIE 6 2015, März. *Energieeinsparung und Wärmeschutz OIB-330.6-009/15*. Wien, Österreich: Österreichisches Insitut für Bautechnik.

ÖNORM B 8110-5 2011, März *.Wärmeschutz im Hochbau – Nutzungsprofile und Klimadaten.* Wien, Österreich: Österreichisches Insitut für Bautechnik.

ÖNORM EN 13779 2007, September 1*. Lüftung von Nichtwohngebäuden – Allgemeine Grundlagen und Anforderungen für Lüftungs- und Klimaanlagen und Raumkühlsysteme.* Wien, Österreich: Österreichisches Insitut für Bautechnik.

ÖNORM EN ISO 7730 2006, May 1, *Ergonomie der thermischen Umgebung – Analytische Bestimmung und Interpretation der thermischen Behaglichkeit durch Berechnung des PMV- und des PPD-Indexes und Kriterien der lokalen thermischen Behaglichkeit. Wien, Österreich: Österreichisches Insitut für Bautechnik.*

Onset Computer Corporation 2012, March. *HOBO Temperature/Relative Humidity/Light/External Data Logger.* Retrieved 15 November 2016 from: *http://www.onsetcomp.com*

Qendra e Publikimeve Zyrtare 2008, Nentor. *Permbledhje Legjislacioni per Ndertimet*. Albania. ISBN 978–99956–631–1-7

Qiriazi P., 2006. *Gjeografia fizike e Shqiperise*. Shtepia Botuese e Librit Universitar, Tirane, pp. 9, 346.

Republic of Albania Council of Ministers 2008, March. *National Strategy for Development and Integration 2007 - 2013.* Tirane, Albania. Retrieved 1 February 2017, from: http://unstats.un.org/unsd/dnss/docViewer.aspx?docID=2198

Szokolay SV, 2004. *Introduction to Architectural Science: The Basis of Sustainable Design*. Architectural Press, Oxford.

Ura e tabakeve ITIRANAT2 2012. Retrieved 25 January 2017, from: *https://www.wunderground.com/personal-weather-station/dashboard?ID=ITIRANAT2#history/tdata/s20120315/e20120315/mdaily*

Wikimapia 2017. Retrieved January 20, 2017, from: *http://wikimapia.org*

6. Appendix

6.1 Tables illustrating the educational institutions in Albania

Table A- 1 Educational institutions in Albania (INSTAT 2010)

Education	05-06	06-07	07-08	08-09
Total	3933	3763	1752	3907
Pre-school	1649	1667	1752	1774
Private sector	76	78	86	89
Primary & lower sec.	1817	1595	1604	1605
Private sector	92	105	120	120
Upper secondary	453	481	489	489
Private sector	77	93	106	106
Tertiary education	14	20	25	25
Private sector	4	9	14	14

Table A- 2 Number of the classrooms, students and groups per year according to the age of the students, depending on the number of the inhabitants the school is situated in (Ministry of Education and Science 2002)

No. of inhabitants, the school is situated in	School type	Students' age (in years)	Class	No. of students per school	No. of students per year	No. of students per group Min/max/ average	No. of groups per each academic year
Approx. 2000-10000	Elementary and middle-school	6-10 10-14	1-4 1-6	250-500 Max.600-850	30-150	18/35/30	2-4
Approx. 10000-120000	Elementary middle-school and high-school	6-10 10-14 14-18	5-10 7-10	1200	150-300	20/35/30	3-6
Approx. 60000-120000	High-schools	14-18	11-13	Max. 1500	Min. 80-100	High schools 18/28/23 Professional schools 13/30/22	Min 4

6.2 Psychometric analysis - schools A and B

Psychometric analysis is illustrated in the following figures for one of the observed rooms for school A (classroom facing north TCN) and B (classroom facing west VCW).

Indoor air temperature and relative humidity for TCN in school A during February, March and April, are displayed in Figures A-1 to A-3.

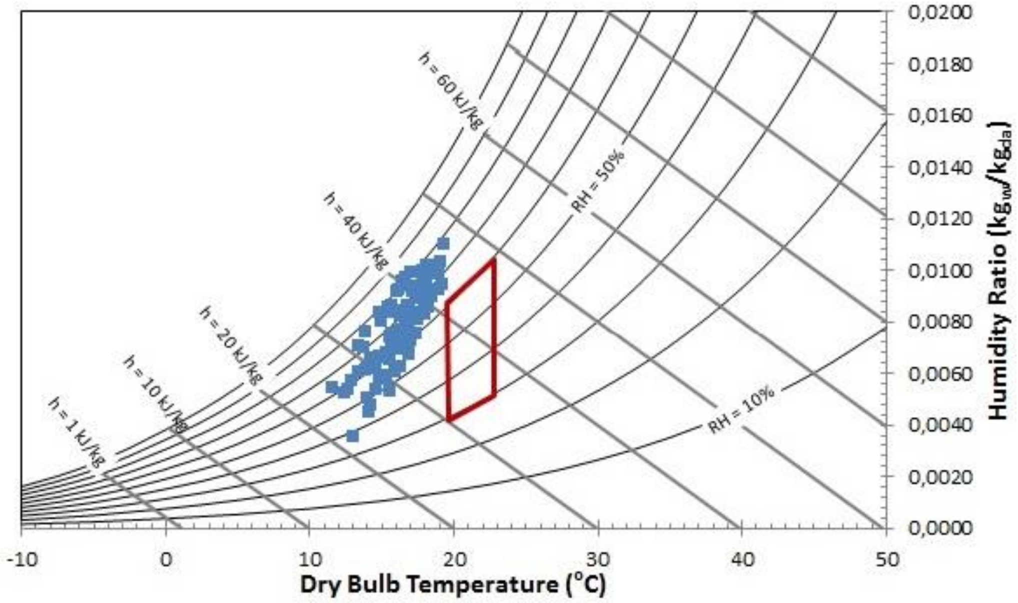

Figure A - 1 Mean hourly indoor air temperature and relative humidity in TCN together with thermal comfort zone, in February

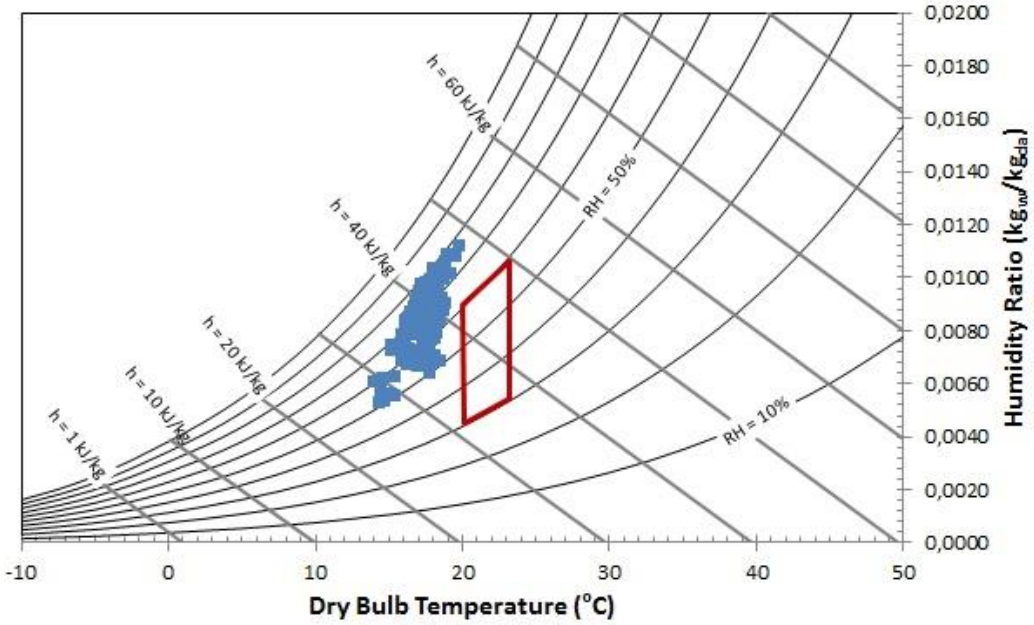

Figure A - 2 Mean hourly indoor air temperature and relative humidity in TCN together with thermal comfort zone, in March

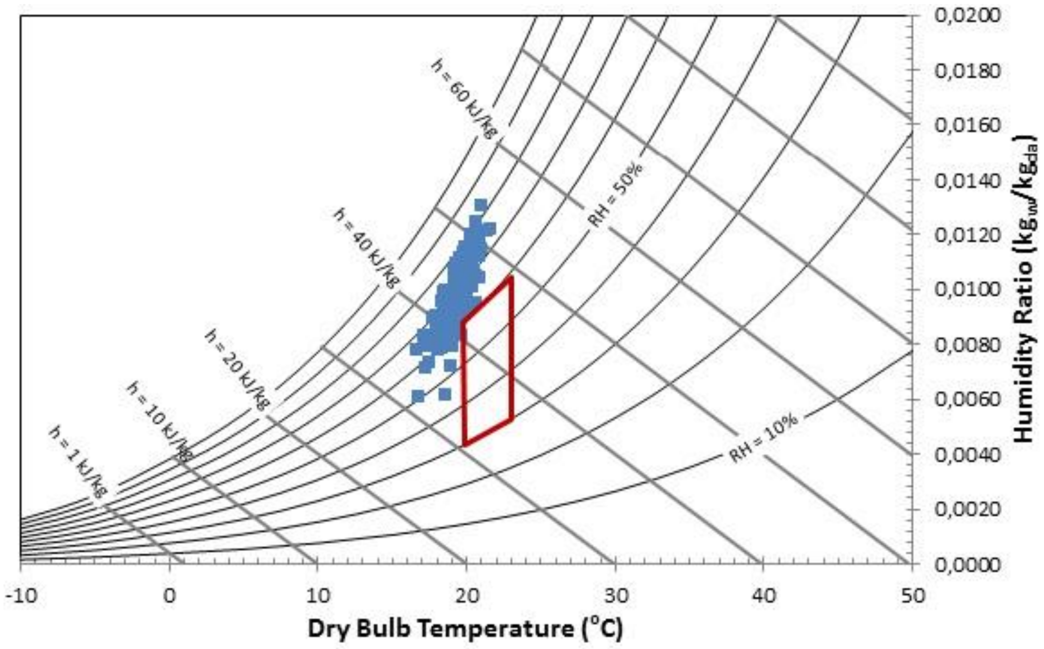

Figure A - 3 Mean hourly indoor air temperature and relative humidity in TCN together with thermal comfort zone, in April

Figures A-4 to A-6 illustrate the indoor air temperature and relative humidity in February, March and April, for classroom facing west (VCW) in school B.

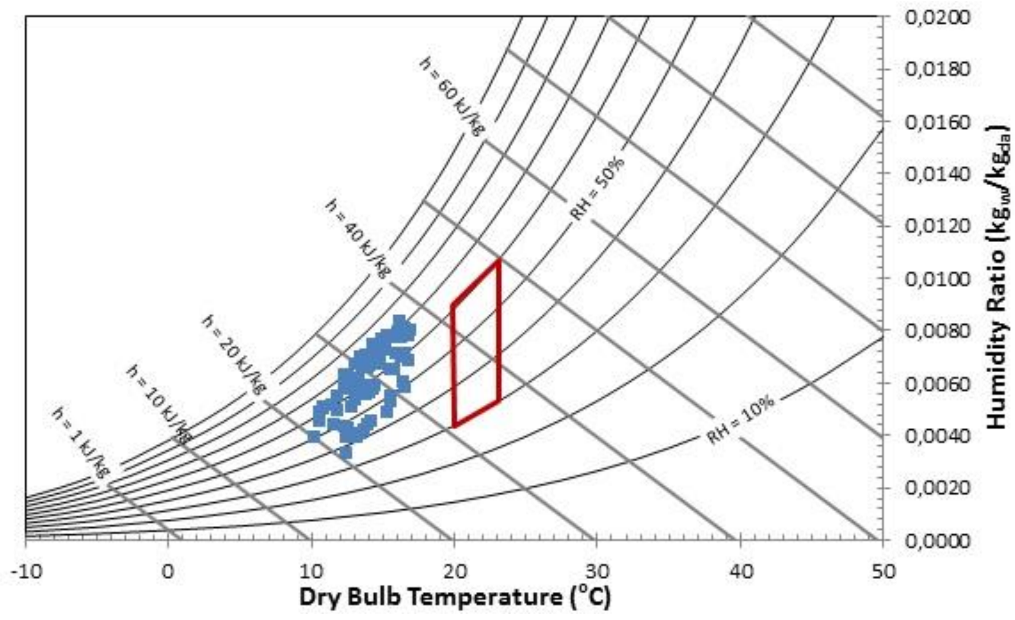

Figure A - 4 Mean hourly indoor air temperature and relative humidity in VCW together with thermal comfort zone, in February

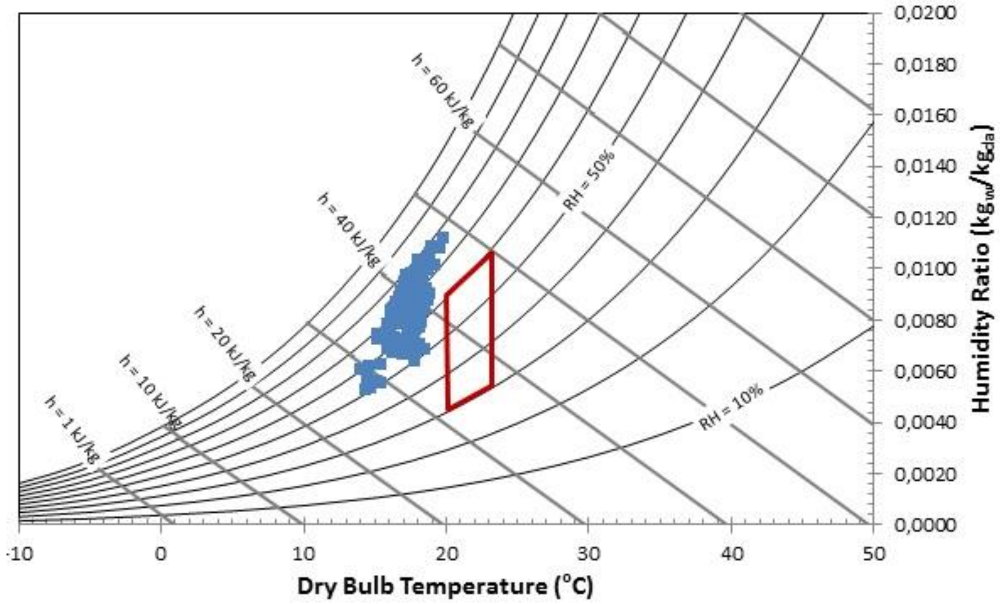

Figure A - 5 Mean hourly indoor air temperature and relative humidity in VCW together with thermal comfort zone, in March

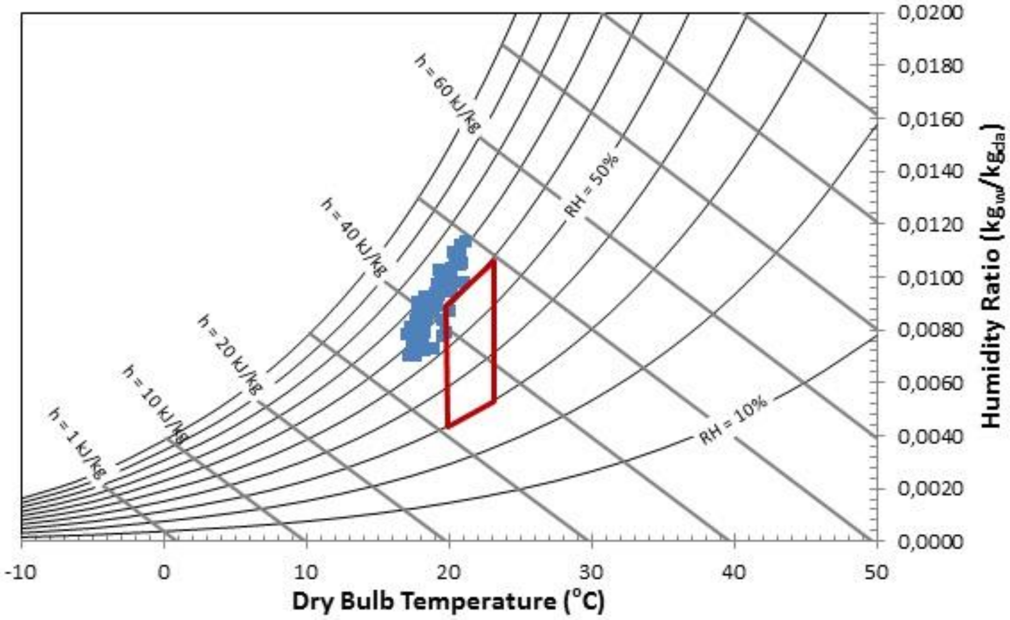

Figure A - 6 Mean hourly indoor air temperature and relative humidity in VCW together with thermal comfort zone, in April

6.3 Building constructions of the assessed schools

Table A- 3 Building materials of school A

Layer	Width [mm]	Thermal conductivity [$Wm^{-1}K^{-1}$]	Density [kgm^{-3}]	Heat capacity [$Jkg^{-1}K^{-1}$]
External walls				
Plaster	20	0,72	1680	837
Brick	20-38	0,70	1800	880
Plaster	20	0,72	1680	837
Internal walls				
Plaster	20	0,72	1680	837
Brick	12-25	0,70	1800	880
Plaster	20	0,72	1680	837
Floor to the ground				
Tiles	20	1,0	2300	800
Mortar	10	0,9	1800	910
Light. concrete	10	0,38	1200	1000
Insulation	20	0,037	25	1340
Concrete	150	1,16	2000	920
Asphalt	20	0,43	1600	1000
Sand, Kies	200	0,55	1580	1057
Soil	600	0,33	1515	796
Basement ceiling/ground level floor				
Tiles	20	1,0	2300	800
Mortar	10	0,9	1800	910
Light. concrete	10	0,38	1200	1000
Insulation	50	0,037	25	1340
Concrete	250	1,16	2000	920
Plaster	20	0,72	1680	837
Upper level floor/ceiling				
Tiles	20	1,0	2300	800
Mortar	10	0,9	1800	910
Light. concrete	10	0,38	1200	1000
Concrete	150	1,16	2000	920
Insulation	50	0,037	25	1340
Brick	100	1,33	2000	920
Plaster	20	0,72	1680	837
Flat roof				
Plaster	20	0,72	1680	837
Concrete	250	1,16	2000	920
Insulation	170	0,037	25	1340
Mortar	10	0,9	1800	910
Asphalt	20	0,43	1600	1000
Pitched roof				
Plaster	20	0,72	1680,0	837,0
Ins./wood beams	170	0,037	25,0	1340,0
Air upw. flow	10	0,0	0,0	0,0
Asphalt	5	0,43	1600,0	1000,0
Tile	10	2,0	2700,0	753,0

Table A- 4 Building materials of school C

Layer	***Width [mm]***	***Thermal conductivity [Wm⁻¹K⁻¹]***	***Density [kgm⁻³]***	***Heat capacity [Jkg⁻¹K⁻¹]***
External walls				
Plaster	20	0,42	1200	837
Block	200	0,32	1040	1050
Insulation	30	0,021	30	1500
Insulation	50	0,031	30	1500
Block	100	0,32	1040	1050
Plaster	20	0,42	1200	837
Internal walls				
Plaster	20	0,72	1680	837
Brick	10-20	0,70	1800	880
Plaster	20	0,72	1680	837
Floor to the ground				
Tiles	20	1,0	2300	800
Mortar	10	0,9	1800	910
Light. concrete	10	0,38	1200	1000
Insulation	150	0,037	25	1340
Concrete	200	1,16	2000	920
Asphalt	10	0,43	1600	1000
Sand, Kies	200	0,55	1580	1057
Soil	600	0,33	1515	796
Upper level floor/ceiling				
Tiles	10	1,0	2300	800
Mortar	10	0,9	1800	910
Light. concrete	10	0,38	1200	1000
Insulation	100	0,037	25	1340
Concrete	250	1,16	2000	920
Plaster	20	0,72	1680	837
Pitched roof				
Plaster	20	0,72	1680,0	837,0
Ins./wood beams	200	0,037	25,0	1340,0
Air upw. flow	10	0,0	0,0	0,0
Asphalt	10	0,43	1600,0	1000,0
Tile	10	2,0	2700,0	753,0

Table A- 5 Building materials of school B

Layer	Width [mm]	Thermal conductivity [$Wm^{-1}K^{-1}$]	Density [kgm^{-3}]	Heat capacity [$Jkg^{-1}K^{-1}$]
External walls				
Plaster	20	0,90	1800	910
Brick	25	0,72	1800	880
Plaster	20	0,90	1800	910
Internal walls				
Plaster	20	0,90	1800	910
Brick	12-25	0,72	1800	880
Plaster	20	0,90	1800	910
Floor to the ground				
Tiles	20	1,0	2300	800
Mortar	10	0,9	1800	910
Light. concrete	10	0,38	1200	1000
Insulation	50	0,037	25	1340
Concrete	150	1,16	2000	920
Asphalt	10	0,5	1700	1000
Sand, Kies	200	0,55	1580	1057
Soil	600	0,33	1515	796
Upper level floor/ceiling				
Tiles	20	1,0	2300	800
Mortar	10	0,9	1800	910
Light. concrete	10	0,38	1200	1000
Insulation	50	0,037	25	1340
Concrete	250	1,16	2000	920
Plaster	20	0,72	1680	837
Flat roof				
Plaster	20	0,72	1680	837
Concrete	250	1,16	2000	920
Insulation	170	0,037	25	1340
Mortar	10	0,9	1800	910
Asphalt	20	0,43	1600	1000

6.4 Weather data

Table A- 6 Weather data of Peshkopi (Meteotest 2012)

Month	Average temperature [°C]	Average humidity [%]	Average global radiation [Wm^{-2}]	Average diffuse radiation [Wm^{-2}]
January	0.9	61.5	53.3	25.6
February	1.4	51.7	69.2	32.8
March	4.5	51.7	110.0	57.0
April	7.4	50.3	152.3	54.0
May	11.7	52.4	185.8	71.3
June	14.1	47.4	199.0	75.4
July	16.3	45.6	215.4	72.1
August	16.1	47.2	190.6	65.7
September	11.9	51.0	143.2	52.3
October	9.0	57.7	94.2	39.8
November	4.9	59.3	57.6	30.3
December	1.8	63.4	48.3	23.3

Table A- 7 Weather data of Tirana (Meteotest 2012)

Month	Average temperature [°C]	Average humidity [%]	Average global radiation [Wm^{-2}]	Average diffuse radiation [Wm^{-2}]
January	4.8	50.6	58.6	23.8
February	4.8	42.8	73.0	31.5
March	7.9	43.9	115.8	55.3
April	10.2	45.4	159.1	65.0
May	15.0	45.6	193.2	76.6
June	17.5	40.6	209.2	78.3
July	19.8	37.7	224.7	70.5
August	19.9	39.7	197.8	69.8
September	15.2	45.3	148.1	54.2
October	12.4	52.2	104.0	39.1
November	8.3	52.5	68.6	28.6
December	5.7	52.0	54.5	23.7

Table A- 8 Weather data of Vlora (Meteotest 2012)

Month	Average temperature [°C]	Average humidity [%]	Average global radiation [Wm^{-2}]	Average diffuse radiation [Wm^{-2}]
January	8.3	53.8	55.8	25.7
February	7.2	47.3	73.5	34.6
March	9.2	52.9	118.9	58.7
April	10.2	53.9	157.7	66.7
May	14.7	52.3	192.1	75.5
June	17.2	47.7	206.7	78.3
July	19.8	44.8	216.3	78.4
August	20.1	48.5	189.5	74.2
September	16.3	51.6	143.9	54.1
October	14.6	55.2	99.9	48.2
November	11.0	54.9	63.1	33.4
December	9.1	55.5	50.9	23.7

6.5 Zoning in EDSL TAS

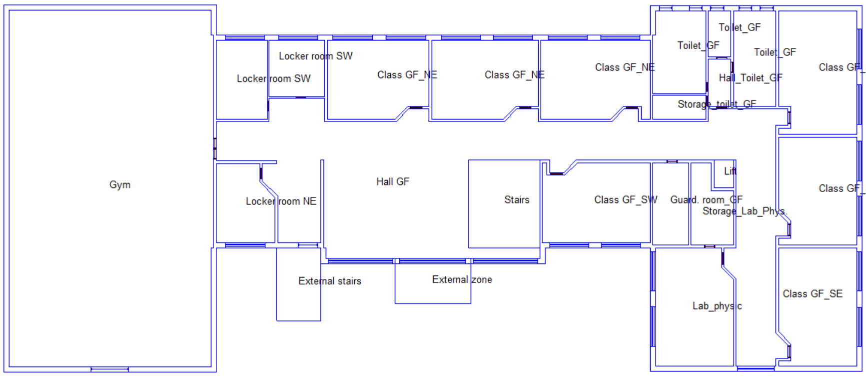

Figure A - 7 Ground floor plan of school C named by zones

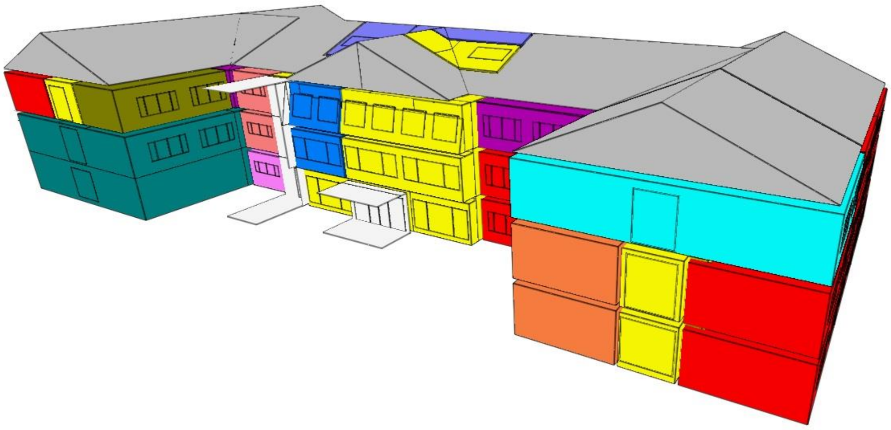

Figure A - 8 School C coloured by zones

Table A- 9 Zones in school C associated with the floor areas and volumes

Name of the zones	Sign	Floor area [m²]	Volume [m³]
Attic *(unheat.)*		539.6	935.5
Uncond. Space		677.31	1116.1
External zone		36.2	245.6
Cabinet		58.8	185.3
Class 1F_NE		90.5	285.2
Class 1F_SE		154.0	485.1
Class 1F_SW		47.9	150.7
Class 2F_NE		183.7	578.8
Class 2F_NW		100.5	316.5
Class 2F_SE		102.0	321.2
Class GF_NE		137.6	433.4
Class GF_SE		154.0	485.1
Class GF_SW		47.9	150.7
Computer Lab		52.1	164.1
Dentist		26.9	84.7

Name of the zones	Sign	Floor area [m²]	Volume [m³]
Director		32.9	103.5
Doctor room		26.9	84.7
Guard. Room		33.8	106.8
Gym		417.5	2776.5
Hall 1F		259.6	817.7
Hall 2F		317.3	986.9
Hall 3F		17.1	45.8
Hall GF		306.0	963.9
Lab_bilogy		51.4	161.9
Lab_chemi		55.7	175.4
Lab_physic		51.4	161.9
Library		83.9	264.3
Lift		3.2	32.3
Locker room		65.8	207.3
Office		39.0	116.8
Psychologist room		20.2	63.5
Polifunc. Space		137.4	432.9
Secretary		5.4	17.1
Stairs		35.7	401.1
Storage_2F		17.2	54.2
Storage_attic		70.2	185.5
Storage_Lab		44.8	141.2
Storage_Toilet		21.9	69.6
Teachers room		98.5	310.4
Toilet_1F		50.1	157.8
Toilet_2F		60.1	189.3
Toilet_GF		53.9	169.9
Toilet_Direc.		3.4	10.6
Toilet_office		3.4	10.6

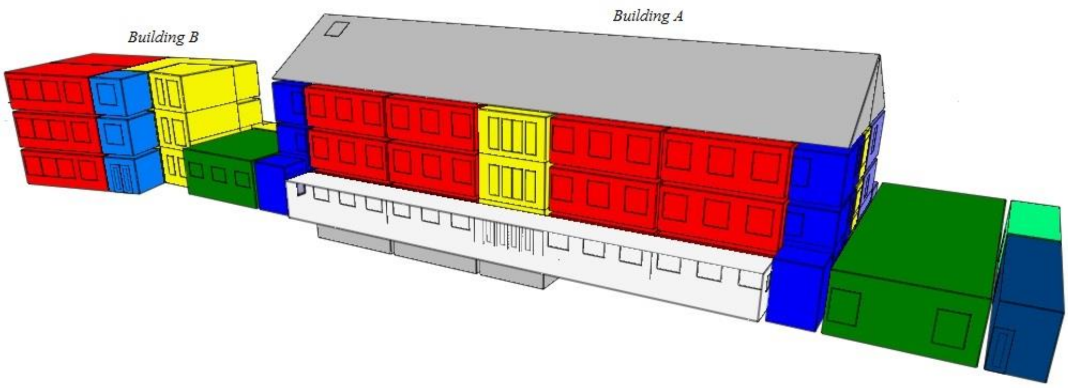

Fig A - 9 School A coloured by zones

Table A- 10 Zones in school A associated with the floor areas and volumes

Name of the zones	Sign	Floor area [m²]	Volume [m^3]
Attic *(unheat.)*		537.3	1132.4
Basement *(unheat.)*		148.8	334.8
Furnance chamber *(unheat.)*		11.4	33.7
External zone		97.71	288.3
Bathroom_A0		29.6	114.0
Cafeteria		60.7	233.6
Class_small		26.3	77.6
Class1_A0_NE		38.4	113.4
Class1_A0_SW		76.3	225.0
Class1_A1_SW		76.9	227.0
Class2_A2_SW		76.9	227.0
Class2_A0_NE		39.7	117.2
Class2_A0_SW		76.8	226.5
Class2_A1_SW		76.8	226.5
Class2_A2_SW		76.8	226.5
Class_BO_N		42.0	123.9
Class_BO_S		42.0	123.9
Class_B1_N		41.1	124.3
Class_B1_S		41.9	123.5
Class_B2_N		42.1	124.2
Class_B2_S		41.7	123.0
Com. room-A1		39.1	115.2
Dentist_A0		13.6	40.0
Dep.Director 1_A1		26.3	77.6
Dep.Director 2_A2		24.83	73.2
Director_A1		24.9	73.2
Dressing room_A0		19.9	76.4
Gym		142.5	548.8
Hall_A0		208.8	635.0
Hall_A1		96.6	285.0
Hall_A2		96.6	285.0
Hall_B1		35.1	103.5
Hall_B2		35.2	103.8
Lab_Biology_A2		39.7	117.2
Lab_Chemi_A2		39.1	115.2
Lab_Physic_A1		39.7	117.2
Library_A2		52.3	154.2
Offirce_B0		9.4	27.9
Offirce_B1		9.4	27.9
Offirce_B2		9.5	28.0
physician_A0		23.8	77.2
Stairs_A		27.8	265.1
Stairs_B		22.5	208.0

Name of the zones	Sign	Floor area [m²]	Volume [m³]
Storage gym		20.3	65.8
Storage com.room		15.7	46.4
Storage Lab		45.1	133.1
Teacers room_A1		52.3	154.2
Toilet1_A0		23.6	76.1
Toilet1_A1		15.4	45.3
Toilet1_A2		15.4	45.3
Toilet2_A0		21.1	67.9
Toilet2_A1		14.4	42.4
Toilet2_A2		14.4	42.4
Wrestling room_A0		60.7	233.6

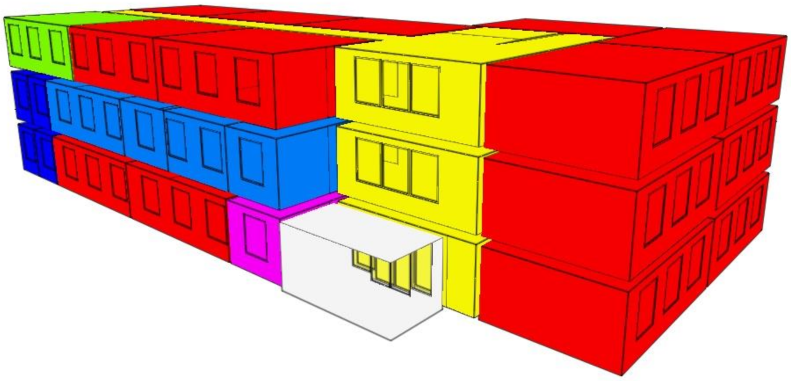

Figure A - 10 School B coloured by zones

Table A- 11 Zones in school B, associated with floor areas and volumes

Name of the zones	Sign	Floor area [m²]	Volume [m³]
Class GF_W_S		39.5	108.7
Class GF_W		39.5	108.7
Class GF_SW		38.4	105.5
Class GF_S		124.0	341.1
Class GF_N		82.7	227.4
Class 1F_S		124.0	341.1
Class 1F_SW		38.4	105.5
Class 1F_W		79.0	217.4
Class 2F_N		82.7	227.4
Class 2F_S		124.0	341.1
Class 2F_SW		38.4	105.5
Class 2F_W		79.0	217.4
Computer room		41.3	113.7
Director 1F_N		22.6	62.2
Hall GF		94.1	258.8
Hall 1F		94.1	258.8
Hall 2F		94.1	258.8
Library		17.3	47.7

Name of the zones	Sign	Floor area [m²]	Volume [m³]
Office-1F_N		35.4	97.4
Stairs		14.0	125.2
Teachers room		41.3	113.7
Toilet		45.5	125.06

6.6 Additional simulations

Additional simulations are made based on the heating applied during the occupancy hours and in 24 hours (if these buildings would be heated 24 hours a day) together with the coldest climate data of the selected cities (weather file of Peshkopi). Figure A-11 and table A-12 show the comparison predicted heating load for school A together with weather file of Tirana (W-TR) and weather file of Peshkopi (W-PE) during occupancy hours and in 24 hours (W-PE_24h).

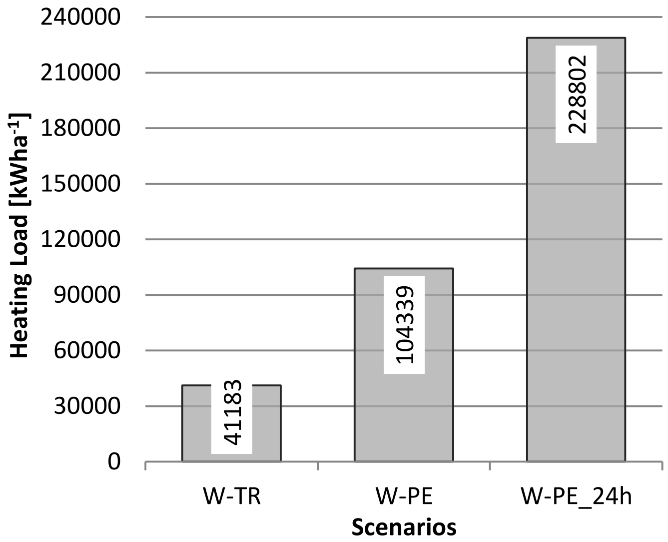

Figure A - 11 Comparison predicted annual heating load for school A computed with W-TR, W-PE and W-PE_24h

Table A- 12 Scenarios of the heating loads for school A computed with W-TR, W-PE and W-PE_24h

Heating loads (HL) for school A - scenarios	HL per square meter (netto) [kWhm^{-2}a^{-1}]
HL computed with the W-TR	19.1
HL computed with the W-PE	48.4
HL computed with the W-PE, heated in 24h	106,1

Similar to school A, Figure A-12 and Table A-13 show the comparison predicted heating load for school B together with weather file of Vlora (W-VL) and weather file of Peshkopi (W-PE) during occupancy hours and in 24 hours (W-PE_24h).

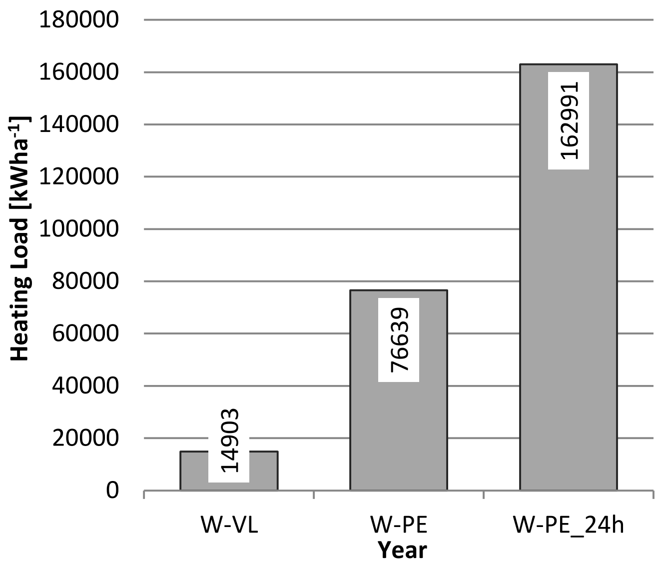

Figure A - 12 Comparison predicted annual heating load for school B computed with W-VL, W-PE and W-PE_24h

Table A- 13 Scenarios of the annual heating loads for school B computed with W-V, W-PE and W-PE_24h

Heating loads (HL) for school B - scenarios	**HL per square meters netto [kWhm^{-2}a^{-1}]**
HL computed with the W-VL	10.1
HL computed with the W-PE	51,9
HL computed with the W-PE, heated in 24h	110,5

The annual heating load for school A calculated with W-PE is 2.5 times higher than HL calculated with W-TR (Table A-12). Table A-13 display HL of school B computed with W-PE, which is five times higher than HL calculated with W-VL.

If school A and B will be heated 24hours a day, calculated with W-PE, it will have the annual heating load approximately twice as high as the heating load calculated during the occupancy hours.

7. Index

7.1 List of figures

7.2 List of tables