**EVALUATING ENERGY SAVING SCHOOL FEATURES AND STUDENTS’ COMFORT IN CENTRAL PRISTINA STATE SCHOOLS**

**by**

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# Abstract

Energy management and efficiency along with environmental issues specifically in buildings is a growing concern. Schools as one of the most-spread public buildings can greatly contribute to energy saving and education. However, schools should prove their contributions by practice at first. This practice can be viewed from students’ and staff’ energy behavior to building design, from number of students to energy types used in school buildings since there are several factors affecting a school’s energy performance and efficiency. This thesis deals with school type, students’ shift, building age, the number of buildings, floors and students, total school size, students’ density, floor height, extra building and energy types used in the schools to find out energy saving school features for the state primary and secondary schools in Pristina Central Municipality. The research results show that state schools investigated consume considerably less energy and produce a smaller amount of carbon dioxide than the schools in the European Union. However, stunningly lower levels of energy consumptions and carbon dioxide emissions cannot be considered as a success since providing students comfortable environment presents another aspect of school energy practice success. Thus, as the second stage of the research, this thesis also compares the highest and the lowest energy consuming state primary and secondary schools in Pristina Central Municipality from the point of students’ comfort levels with the help of Örebro Survey. The comparisons are carried out to find out complaint level differences based on students’ location in their classrooms and the number of attended lessons. between the two groups of the schools. The comparative research results indicate that school energy performances specifically in low energy consuming schools should be handled together with students’ health, well-being and comfort along with environmental issues.

**Keywords:**Energy consumption, school, students’ comfort

# Abstrakt

Menaxhimi i energjisë dhe efikasitetit së bashku me çështjet e mjedisit, në mënyrë të veçantë në ndërtesa është një shqetësim në rritje. Shkollat, si një nga ndërtesat publike më të përhapura mund të kontribuojnë në masë të madhe ne kursimin e energjisë dhe arsimimin e gjeneratave te reja. Megjithatë, shkollat duhet të vërtetojnë se po punojnë në praktikë në fillim. Kjo praktikë mund të vërehet nga sjellja e studentëve 'dhe stafit', për ndërtimin e projektimit, nga numri i nxënësve e deri te llojet e energjisë të përdorura në objektet shkollore; përderisa ka disa faktorë që ndikojnë në performancën e energjisë e një shkollës dhe efikasitetit. Kjo tezë ka të bëjë me llojin e shkollës, "ndryshimet, vjetërsia e ndërtimit, numri i ndërtesave, dyshemetë dhe nxënësit, madhësia totale e shkollës, dendësia e numrit të studentëve, lartësia e dyshemeve, për tëkuptuar mënyrën më të lehtë për të implementuar praktika për mbrojtjen e mjedisit. Rezultatet e hulumtimit tregojnë se shkollat shtetërore në vend konsumojnë në mënyrë të konsiderueshme më pak energji, dhe prodhojnë edhe një sasi më të vogël të dioksidit të karbonit sesa shkollat në Bashkimin Evropian. Megjithatë, nivelet magjepsëse të ulëta të konsumimit të energjisë dhe emisionet e dioksidit të karbonit nuk mund të konsiderohen si një sukses për shkak se ofrimi i një hapësireje të rehatshme për studentët është një ndër qëllimet kryesore të praktikave për ruajtjen e ambientit. Kështu, si në fazën e dytë të hulumtimit, kjo tezë krahason edhe përdorimin më të lartë dhe më të ulët të energjisë që konsumojnë shkollat fillore shtetërore dhe shkollat e mesme në Prishtinë; komunën qendrore, nga pikëpamja e nivelit të komoditetit të nxënësve, me ndihmën e Anketës Örebro. Krahasimet janë kryer për të gjetur dallimet në nivelet e ankesave, bazuar në vendndodhjen e nxënësve në klasat e tyre dhe numrin e mësimeve që kanë ndjekur. Rezultatet e krahasimit tregojnë se përdorimi i energjisë, sidomos në shkollat qe kanë përdorim të ulet, duhet të mirret parasysh bashkë me shëndetin e nxënësve, konfortin dhe mirëqenien – dhe mjedidin.

**Fjalet Kyçe:** konsumim i energjise, shkollë, rehati

# Dedication

Humbly, To My Family, All Educators and Families

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# Declaration Statement

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Ibrahim Can Korkut

June 13, 2017

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# LIST OF ABBREVIATIONS

ACEEE : American Council for an Energy-Efficient Economy ALB : Albania

ANN : Artificial Neural Network

ANSI : American Nation Standards Institute

ASHRAE : American Society of Heating, Refrigeration, and Air Conditioning BER : Building Energy Rating

BIH : Bosnia and Herzegovina

BMS : Building Management Systems BP : British Petroleum

Btu : British thermal units

CFL : Compact Fluorescent Light

CIBSE : Certified Institute of Building Services CII : Construction Industry Institute

CISCA : Ceiling & Interior Systems Construction Association kgCO2/m2/yr: annual CO2 emission per surface area

CRO : Croatia

DD : Degree-Days

DEC : Display Energy Certificate DEC : Display Energy Certificate

DfES : Department for Education and Skills EE : Energy Efficiency

EHCS : English House Condition Survey EIA : Energy Information Administartion EMC : Energy Conservation Measure

EP : Energy Performance

EPBD : Energy Performance of Buildings Directive EPC : Energy Performance Certificate

ERO : Energy Regulatory Office

ESCO : Energy Serving Companies EUI : Energy Use Intensity

EVO : Efficiency Valuation Organization GDP : General Domestic Product

GoK : The Government of Kosovo GPG : Good Practice Guide

HERS : Home Energy Rating System

HVAC : Heating, Ventilating, and Air Conditioning IAQ : indoor air quality

IEC : Indoor Environmental Condition IEQ : Indoor Environmental Quality IFI : international financial institutions

IPMVP : International Performance Measurement and Verification Protocol ISO : International Organization for Standardisation

KEEA : Kosovo Energy Efficiency Agency KOS : Kosovo

kWh/m2/yr : annual kilo watt energy per unit area / meter square

kWh/m3/yr : annual kilo watt energy per unit volume KEEA : Kosovo Energy Efficiency Agency KEEP : K-12 Energy Education Program

LEED : Leadership in Energy and Environmental Design MAXECS : Maximum Energy Consuming State School MED : Ministry of Economic Development

MEP : Mechanical, Electrical and Plumbing

MESP : Ministry of Environment and Spatial Planning MINECS : the minimum energy consuming state school MKD : the Former Yugoslav Republic of Macedonia MLGA : Ministry of Local Government Administration MMS : Modernization of Municipal Services MNECB : Model National Energy Code for Buildings

MoF : Ministry of Finance

MOL : Moldova

MNE : Montenegro

MTI : Ministry of Trade and Industry

NEED : National Energy Education Development NZE : Nearly Zero Energy

ODPM : Office of Disaster Preparedness and Management

OECD : The Organization for Economic Cooperation and Development PE : Public Economic

PF : Public Financial

PI : Public Institutional

PIR : Passive Infra Red

PLR : Public Legal and Regulatory PMV : Predicted Mean Vote

PPD : Predicted Percentage Dissatisfied ppm : parts per million

PPP : Purchasing Power Parity PCM : Pristina Central Municipality PQA : Power Quality Analyser

ROI : Return on Investment

SEAI : Sustainable Energy Authority of Ireland SER : Serbia

st/m2 : Student Density (student/metre square)

TPES : [Total Primary Energy Supply](https://en.wikipedia.org/wiki/Total_primary_energy_supply) UKR : Ukraine

WBI : Western Balkan Investment

WBIF : Western Balkan Investment Framework

$/m2/yr : annual cost per surface area

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# CHAPTER 1

**INTRODUCTION**

## Introduction and Background

Increasing energy consumptions along with its ecological and economic consequences is presenting one of the most significant problems today. In addition, people demand higher levels of comfort and living standards with the help of technological developments. In this manner, M. Jefferson (2014) states that:

The challenges to the future of the human race embodied in growing world population, and limited resources, find many in a state of denial. The exploitation of fossil fuels, and efforts to expand the availability of low carbon energy technologies, are seen by an increasing number of observers to place the “great acceleration” of economic growth and material living standards under fundamental pressure (Jefferson, 2014).

It is clear from his statement that using energy efficiently has become of great importance. On the other side, people demand better living standards. Vaclav Smil (1994) claims that energy use has influenced economies and societies to transform from farming-based civilizations to societies with universal cultures and has significantly improved literacy and people’s average life span. It has also broken economic borders. Undoubtedly, so much influence requiring more investments has found some responses in business.

Thus, energy consumption and demand on higher levels of living standards are bound to be handled together and effectively by also taking the deterioration of conventional energy resources and environmental impacts of increasing energy consumption into consideration.

According to Ayres and Vlasios, “the increased stock of capital and the supply of useful energy due to the discovery and exploitation of relatively inexpensive fossil fuels” (Ayres & Vlasios, 2014) have been the main engines behind the growth after the Industrial Revolution. Today, we still by 80% depend on fossil fuel for global energy (Jefferson, 2014) and the role of renewable energy resources is still small. However, the growing concerns for depleting natural energy resources and environment have made energy conservation and efficiency the first fuel. First of all, there is energy loss due to practical limits. For instance, energy loses its original quality when it is transformed. Cullen and Allwood (2010) inform that 66% of final energy is not converted into useful energy and there is over 70% loss in transportation, 62% in industrial, and 60% in commercial and residential. Buildings in European Union count for the 40% of overall energy consumption and responsible for the 36% of total CO2 emissions (Thewes et. al, 2014). Buildings over 50 years old that sum up 35% of all the buildings and old buildings use 25 lt oil on average in a year while the average of recently built ones is less than 5 lt of oil a year (European Commission, n.d.). Global building energy consumption is ranged between 20% and 40% with an expectation of fast upsurge in the future (Pérez-Lombard et al., 2009). According to Menezes et al. (2011) the difference between measured and predicted electricity demands is around 60–70% in favor of the measured one in general offices and schools while it can be as high as over 85% in university campuses.

These figures along with many others suggest massive energy conservation opportunities and the European Union took a step through the Energy Performance of Buildings Directive (EPBD) 2002/91/EC, and implemented a strategy to lessen the primary energy use by 20% by 2020 (European Council, 2007) and demanded from all its members to take precautions for more buildings with nearly zero energy with European directive 2010/31/EU to down energy consumption differences between the Union members (The European Parliament and the Council of the EU, 2010). Accordingly, all the Union members are urged to establish bottom prerequisites and cultivate methods to regulate building energy performances and have more energy

efficient constructions by the end of 2020 (The European Parliament and the Council of the EU, 2010). In October 2014, they agreed a higher energy savings target of 27%, or greater by 2030, following a proposal for an energy efficiency (EE) plan up to the year 2050 in 2011 and an energy efficiency directive for indicative energy efficiency targets in 2012 (EUR-Lex, 2015).

In this manner, governments and municipalities carry great responsibilities to build and apply criteria on building constructions and management. For instance, The UK government has targeted an at least 80% drop in CO2 emissions by the year 2050 (Department of Energy and Climate Change, 2013) as UK schools present an opportunity to cut down their yearly energy expenses by roughly £44 million (Carbon Trust, 2012). Furthermore, the built environment poses as much as twice cost-effective carbon mitigation in comparison to any other sector (Green Building Council, 2011). Naturally, these figures require some further implementations concerning building energy labeling and certificates. Energy labeling in EU, similar to product labeling, has been in practice with the EPBD, supported with energy disclosure legislations/laws and an advantage of a common metric. Scientific researches show that building energy labeling is a substantially rewarding application (Fuerst & McAllister, 2011). Labeling and energy efficiency audits were long suggested as strategies against irregularity of building energy information (Hirst & Brown, 1990) although it is difficult to speak about definite fruitfulness of energy auditing through the academic literature. For instance, while Anderson and Newell’s (2004) research results value governments’ support “on industrial users to implement energy efficiency projects”, according to Schleich’s (2004) results, number of auditors with less energy consumption is very limited. The results in a positive or negative way, may have faced and may face some miscalculating problems such as inappropriate analysis tools and methods, or policy misapplications such as neglecting users’ comfort. Thus, as Thewes et al. (2014) claim, collecting, classifying and analyzing valid data valid data will gradually turn out to be vita in the future.

Thus, data collection on energy consumption demands great attention not only from the point of statistics but also from the point of trends, energy policies, future planning and economic issues. International institutions from such as European Environment Agency have collected and published energy-related data regularly. Also, British Petroleum (BP) since 1951 has significantly contributed to data collection and publishing efforts.

Energy management as a crucial concept and practice also plays a significant role to save energy and improve energy efficiency. Sri Lanka Sustainable Energy Authority (2012) summarizes energy management processes as gathering the data, finding opportunities and their potential savings, taking measures and evaluating outcomes. After fulfilling the last step, a continual repetition from step one should be applied.

A repetitive energy consumption survey along with a well-organized data collection and tracking form is essential for any organization to build a baseline, concentrate over- energy-consuming functions to take appropriate measures and take proper management decisions. Meticulous work on energy bills/meters and comparing energy bills/meters with similar structures are also useful steps to identify what malfunctions. It is clear that collection and analyses of energy data play a vital role on energy management as well.

However, data on building energy consumptions are not sufficient enough since types of buildings and activities taken place in them greatly vary. Green Building Council (2011) states that it is impossible to cut energy use lacking good data. Data/Information on real-time performance will reveal differences between the actual performance and design, and later on the building energy certificate. Energy efficiency as a means of closing the breach between the theory and real-time performance gains great importance as the rich and cheap resources of oil may be coming to an end while industrial developments rely on oil. Information, specifically the one that compares the real-time and design/predicted performances in repeated cycle of regathering, will be useful for designers, city planners, owners, analyzers, policymakers and academicians/scientists.

Additionally, building energy information is becoming compulsory for municipalities and local authorities due to new legislations and laws to increase energy efficiency and reduce CO2 emission. Building energy information can also be beneficial even without labeling procedures. Information on building energy performance allows users, owners and most importantly designers to compare similar buildings with more and less energy efficient buildings to improve building energy designs and develop better building energy policies. The building stock in hand should be analyzed well to build energy policies, building energy labeling standards and building energy certificates. However, collecting statistically sufficient and valuable information requires great workload by the whole stakeholders associated with construction practice and the collected information should be tested, regulated and analyzed before making use of it. The criteria on collection, verification, regulation and analysis of the information may need reshaping to improve users’ comfort and health conditions, energy efficiency and cost effectivity. Building energy efficiency and performance cannot be improved without sufficient information since owners and users should be certain about cost-effective investments. Moreover, building energy information, specifically building energy labels and certificates allow buyers, sellers and tenants to compare the building with similar but more energy effective ones.

Energy consumption is also meaningful from the point of economic growth. In spite of the fact that whether economic output increases energy consumption or vice versa is not certain, researches show that these two concepts are related (Ozturk, 2010; Payne, 2010). A production function depicts how economic inputs are converted into economic outputs and energy is one of those inputs. Changes among inputs, types of energy as an input and/or output, type of output such as services and manufactured goods, type of economy such as labor or capital-intensive can vary the effect of energy on economic success or growth. For instance, outputs as services require more energy for each unit of output. Judson et al. (1999) agree that time-effects show that energy consumption in industry and construction is staying the same, even lessening. Thus, the correlation between energy

and economic growth strongly depends on interaction between the use of energy and production. Additionally, having taken into account that 40% of all the energy produced is spent in non-industrial buildings (European Commission, n.d.) and the world’s population keeps growing, it is possible that energy consumption and economic growth may not follow parallel paths. However, it was calculated that USD 1 trillion could be saved only by immediately and globally implementing the 25 Energy Efficiency Policy Recommendations by the International Energy Agency (Pasquier, 2013).

This research focuses on school figures as school type, students’ shift, building age, number of building floors and students, total building area, floor height, extra buildings, student density and fuel type that affect energy consumption.

Users’ including students’ health, well-being and comfort also play an important role in building energy consumption as building are places where people pass great amount of time. If better working environment or Indoor environmental conditions (IEC) enhances people’s “creativity, interaction and sharing of knowledge and ideas” (Pinder et al., 2009), it perfectly fits for educational facilities since their chief purposes are to share and distribute knowledge. As the notion of wellbeing is complicated to describe, it is wise to define it with environmental qualities. Therefore, educational buildings should offer physically and spiritually comfortable indoor environment for students to have better concentration for better outcomes. IECs mainly refer to thermal, air, acoustic and air comfort in buildings. Roelofsen (2002) states that thermal and air qualities are the most important ones and they are highly related. The reason for thermal comfort to collect more research attention (de Carvalho et al., 2013) can be that it affects building energy uses more than the others (Corgnati et al., 2009) and students’ and teachers’ performance (Lee et al., 2012).

Healthier indoor environmental qualities can enhance students’ learning practice while lessening building energy consumption (the American Society of Heating, Refrigeration

and Air Conditioning Engineers - ASHRAE, 2008). Lack of any of these qualities can lead to sick building syndrome (Bluyssen et al., 2011). School activities mostly demand mental stability and students may get mentally exhausted during activities. It is clear that unfavorable environmental conditions will not help students to refresh their mental power. However, studies on school buildings’ environmental conditions are not promising. For instance, a research on 66 German schools released that CO2 levels were very high (Desideri & Proietti, 2002). A random sampled research on 100 schools in Denmark in 2009 revealed higher than the maximum recommended level of 1000 ppm CO2 concentration on average while students were having lessons (Menå & Larsen, 2010). In some cases, air flow/supply was lower than they should be (Pereira et al., 2013)

and in some others the average indoor air temperature was 3-6 OC higher than students

and teachers preferred (Larsen, 2011).

However, school energy consumption figures may change according to the region where the school is located. For instance, the average energy consumption for 117 schools in the Province of Torino was calculated as 100 kWh/m2 whereas it was 472 kWh/m2 for Canada (Dascalaki & Sermpetzoglou, 2011). There is also the other side of the story as Theodosiou and Ordoumpozanis, (2008) state that IEQ as a matter of students’ health is much more important than energy costs. As a result, all stakeholders who take part in education and building industry are to build a good balance between students’ comfort and energy consumption to improve building energy performance. Nevertheless, it is worth mentioning that building comfortable and healthy environment in schools does not depend on only energy but many other factors such as classroom student density, working/learning hours, design, location and structure of the school and the city to allow natural light, solar exposure and natural air ventilation, even building shadowing. From one point of view, studies on school indoor conditions can be divided into two categories as studies dealing with one aspect of indoor conditions and multi- aspect overall comfort perception (Pereira et al., 2014).

## Significance of the Study

Human civilization still heavily depends on depleting natural energy resources, and buildings in European Union count for the 40% of total energy consumption and responsible for the 36% of CO2 emissions in Europe (Thewes et. al, 2014). Department for Children, Schools and Families (2010) in the UK states that annual energy expenditure and carbon emission of schools in the UK are equal to around £400 million and 15% of public sector carbon emission. The figures are financially and environmentally significant enough to support efforts to lessen school energy consumption and carbon emission.

Energy consumption and students’ comfort levels are two interactive issues that should be balanced since students have no choice not to attend lessons or change their schools for a better one if there is. They more often have to learn and practice new things than adults who mostly carry out repetitive responsibilities. However, IEQ in elementary schools in technologically advanced nations are often considerably poorer than the ones in office buildings (Wargocki & Wyon, 2013). However, there were few researches that look into the influence of high temperatures and poor air quality on children’s schoolwork performance before 2005 (Mendell & Heath, 2013). Moreover, worldwide the average CO2 levels in mechanically ventilated schools were 500 ppm lower than naturally-ventilated ones except for other pollutants and bio effluents (Santamouris et al., 2008). Awareness of protective health care, work satisfaction and comfort, energy conservation and efficiency should be taught at early ages for more promising futures. Moreover, energy and education are two key concepts that can fundamentally affect future of countries and even humanity. The research of this dissertation deals with several school features that can affect school energy consumption as the first stage of the dissertation. There are nine school features that the research deals and tries to find energy saving school features to reduce energy consumptions and carbon dioxide emissions. It is the uniqueness of the dissertation that it looks into so many factors about school energy consumption. Also, although the research takes the state primary and secondary schools in Pristina Central Municipality (PCM) as the target research area, the comparative results with the state schools in Vushturi show that they can be applied in other cities of Kosovo or even in other countries if they are supported with further researches. The research results also indicate school energy consumption and CO2 emission averages can be drastically low if the right school features are chosen at the beginning. The results can guide even the existing schools with some minor changes.

The research compares students’ comfort levels between high and low energy consuming schools in the same municipality because low or high energy consumption figures are not very meaningful without occupants’ responses. Comparative results between meticulously detailed subcategories have been analyzed to provide stepping stones for school administrators and school designers to understand the differences between students’ comfort levels within subcategories. The research results indicate that a healthy school/classroom environment should not be aimed as only the average of a school/classroom but as equally distributed for every student sitting/studying at different locations of a school/classroom.

## Purpose of the Study

This study aims to evaluate whether students’ shift, school type, building age, the number of building floors and students, total building area, floor height, extra buildings, student density and fuel types affect school energy consumption. Secondly, it is to compare students’ comfort levels between the schools with low annual energy consumption per student, transparency, and compactness and the schools with high annual energy consumption per student, transparency and compactness. The results and analyses of the first stage of the research will provide Pristina Central Municipality with information for more energy efficient school features while the second stage of the research will provide the information on the differences between their comfort levels according to the specific questionnaire items. The first stage of the research included all the primary and secondary state schools in Pristine Central Municipality and the second stage of the research included the students registered in three high and three low energy consuming state schools along with their building transparencies and compactness as sampling criteria in PCM in the academic year 2014-2015.

## Research Hypotheses

The research addresses the following hypotheses:

1. Study shift as morning and morning + afternoon, number of school building floors and 0.2 st/m2 student density, are statistically significant predictors of annual school energy consumption per student (kWh/st/yr) and unit area (kWh/m2/yr), annual CO2 emission per unit area (kg CO2/m2/yr).
2. Annual school energy consumption per meter square (kWh/m2/yr) can be

statistically significant predictor for annual school energy consumption per student (kWh/st/yr) and annual CO2 emission per unit area (kg CO2/m2/yr).

1. Higher degrees of differences appear between students’ comfort levels in schools with low energy consumption, building transparencies and compactness than schools with high energy consumption, building transparencies and compactness when the attended number of lessons increases.
2. Students in schools with low energy consumption, building transparencies and compactness have higher levels of health problems than students in schools with high energy consumption, building transparencies and compactness.
3. Students in schools with low energy consumption, building transparencies and compactness have higher levels of distraction than students in schools with high energy consumption, building transparencies and compactness.

## Limitations

The results of the first stage of the research can be generalized only to the population of the state primary and secondary schools in PCM. These types of schools are poorly equipped and energy consuming appliances hardly vary. Additional limitations are as given below:

1. It is clear that there might be innumerous factors affecting a school’s energy consumption. This research takes some of them into consideration although some others such as building material and shadowing, its exposure to the sunlight, parents’ financial backgrounds etc. also play important roles in energy consumption. Thus, it is almost impossible to take all the factors into the consideration at once.
2. The second stage of the thesis research was carried out in state secondary schools in PCM since primary school students might have difficulties in answering the survey questions. To build a comparison between the state primary and secondary schools was not attempted.
3. The survey for the second stage was applied in April and it can reflect students’ better emotions. Students’ answers may change for some specific questions in the winter and spring months. Additionally, students’ bias, their desire to protect or discredit their schools and seriousness on the issue reflecting their answers cannot be controlled.

## Delimitations

The population studied for the first stage included only all the primary and secondary state schools in PCM, the state kinder gardens were excluded from the research as their energy fuels and comfort sensitivity greatly differ from the state primary and secondary schools in Pristina Central Municipality. The population studied for the second stage included students only in six state secondary schools in PCM. The findings of the stage were limited to the comparative population studied. Furthermore, the second stage did not consider students’ gender, schools’ success levels and locations as they can reflect student families’ financial and educational background, and can influence students’ well-being in general.

# CHAPTER 2

**LITERATURE REVIEW**

## Energy Conservation

## 2.1.1 Energy Conservation and Efficiency

Energy conservation means reducing energy consumed in any type of structure. Measures taken to save energy, called energy conservation measures (ECMs), are achieved through a range of use of technology and scheme to lower energy usage and consequently bills. The measures can start from replacing more efficient lighting, ventilation means and better insulation applications. Furthermore, residents can apply to organizations such as Residential Energy Services Network in the USA for help. In bigger buildings or organizations, it is recommended to work with companies that work under contracts. The companies follow some procedures to decrease energy consumption and upsurge energy efficiency. For instance, in the USA, Efficiency Valuation Organization provides guidelines for energy conservation and efficiency called [International Performance](https://en.wikipedia.org/wiki/IPMVP) [Measurement and Verification Protocol](https://en.wikipedia.org/wiki/IPMVP) (IPMVP) (EVO, n.d).

Patterson (1996) describes energy efficiency as consuming a reduced amount of energy to harvest the equal volume of services or valuable production. Thus, energy efficiency means producing the same or better total consumption value by consuming less energy (Chung et al., 2006). Although energy efficiency and energy conservation are viewed as the same terms on the surface, the difference is that energy conservation means to reduce energy use by modifying lifestyle/behavior while energy efficiency speaks of restraining energy consumption by using highly efficient appliances (OECD/IEA, 2014). Additionally, while energy conservation means low energy consumption, it also

leads to low energy production (Kandar et al., 2009). However, energy conservation and efficiency are both used for energy intensity development in some analysis such as decomposition. Energy intensity means the sum of energy used for output. Indeed, energy efficiency along with others such as type of industry, energy services and their availabilities, behavior patterns, country size, exchange value rates is one of the features to define energy intensity. Thus, misplacing energy efficiency and intensity may lead to confusing results.

There is no need to say that energy efficiency will also lower energy bills and energy dependency to other countries. A good example of energy efficiency implementation and vivid benefits from that is the state of California. The state implemented their first energy efficiency measures in the 1970s and kept their energy consumption almost the same while it doubled in the USA in the following years proving that energy efficiency is crucially cost-effective (Zehner, 2012, p.180-181). Even what is more striking is that the state followed a strategy that put energy efficiency in the first place, renewable energy in the second while fossil energy driven power plants in the last (California Energy Commission, 2005). Furthermore, only by replacing ten-year-old equipment with more efficient ones, it is possible to decrease annual [CO2](http://en.wikipedia.org/wiki/CO2_emissions) [emissions](http://en.wikipedia.org/wiki/CO2_emissions) in Europe by almost 20 million tons (Electrolux, 2011).

To begin with, buildings themselves are significant factors for in energy efficiency along with advanced energy consuming appliances. Some of the factors influencing building energy efficiency are building location, structures around buildings such as other buildings, trees or natural structures, building envelop and insulation, and building design. For instance, potential energy saving of energy efficient buildings is equal to 144 million tons of tonne of oil equivalent in 2050 totaling to the present energy consumption in UK (IEA, 2013).

Other measurements for energy efficient buildings are:

* + - More energy efficient construction material
    - Renewable energy sources
    - Energy dashboards
    - Natural ventilation
    - Insulation
    - Building Management Systems (BMS)
    - Passive Infra Reds (PIRs) to automatically turn off lights in unoccupied places
    - Advanced thermal implementations
    - [Smart meters](https://en.wikipedia.org/wiki/Smart_meter) with/and Power Quality Analysers (PQAs)
    - [Green Building Extensible Markup Language](https://en.wikipedia.org/wiki/Green_Building_XML) with building energy simulation tools

Consequently, energy efficiency is and will stay as the mainstay of global development objectives for now and many years to come. Yet, the biggest barrier to energy efficiency implementations is the lack of commitment or attention to the issue. According to United Nations Foundation (2007), users’ preferences in building design and material, changing technologies leading to the use of more energy consuming energy appliances are other reasons behind the lack of energy efficiency in buildings.

Jalaei and Jrade (2014) claim that despite all the importance, efforts put into their improvement and their precious results, energy efficiency and sustainability are not “key criteria in the building development process” as they are mostly taken into consideration after the construction which makes retrospective adjusting less effective. Thus, cooperation of all building construction related fields from the early stages is very important (Bouchlaghem et al., 2005).

## Energy Efficiency Indicators

As energy efficiency has gained great importance to evaluate energy performance, the measurement as an indicator is essential. However, the problem of setting an internationally accepted indicator to measure energy efficiency stands alone as there are various definitions. However, energy efficiency indicators can be described as the proportion between the input and useful output of a process in brief (Proskuryakova & Kovalev, 2015).

Concerning school energy consumptions, various energy consumption parameters and consequently indicators are used in literature and researches. Most commonly used ones are kilowatt of energy per unit of building area (kWh/m2) and kilowatt of energy per unit of building volume (kWh/m3). For instance, d’Ambrosio et al. (2010) for schools' yearly energy consumption figures for each country, Katafygiotou and Serghides (2014) for the annual energy consumption of Cyprus schools and Paris (2012) for primary school energy consumptions in Paris use kWh/m2, while Corgnati et al. (2008) use both kWh/m2 and kWh/m3 for district heating energy use and the total electrical energy use as room heights vary (ENEA, 2010). In countries with significantly different climate zone, kWh/m2xGGxanno is also used with GG (gradi-giorno) taking degree-days (DD) into account and fossil fuel and electricity consumptions are separately calculated as in the UK to compare with related benchmarks (Pereira et al., 2014). For instance, according to Hermelink et al.’s (2013) research some of the best practice schools are all-electric schools. Bruhns (2011) attracts attention to the differences between gross floor area and total useful floor area as variables. Some researchers such as Santamouris and Sfakianaki (2009) separate heating energy loads and HVAC system energy consumption. Pereira et al. (2013) proposed that a School Benchmarking Indicator (SBI) based on measured energy consumption should be used rather than Energy Performance Certificate’s theoretical calculation of building energy performance.

## Energy Conservation Measures (ECMs)

Individual and organizational energy consumptions from national scale to international one have social, economic and environmental consequences. These consequences such as energy prices, global warming and pollution, efficiency directories and legislation procedures force everyone to take measures to save energy. Above all the others, one reason itself is significant enough to take measures and it is that we have only one planet to live. It makes energy saving/efficiency a crucial issue for humanity.

From the point of markets, around 40% of energy efficiency market worldwide that is annually around USD 310 billion is financed with debt makes energy efficiency first fuel (IEA, 2014, p.18). Consequently, this huge market brings about some legislation. For instance, in the U.S., all states have built statutes allowing companies to offer energy savings performance contracts with variant levels of success depending on approach, state’s degree of involvement and other factors (Durkay, 2013). Big organizations often apply contracts with energy service companies that follow some guidelines built by international organizations. One of them is International Performance Measurement and Verification Protocol (IPMVP). Although the Protocol does not enact as a legitimate obligation, it delivers a framework to improve energy performance of sustainable energy sources and IEQ (US Department of Energy, 2002, p.iii).

Energy conservation measures are steps taken to reduce energy consumption in an organization or a facility. In simple and small size buildings it can start from changing light bulbs into fluorescent lambs, changing window frames, checking heating, ventilating, and air conditioning (HVAC) systems. On a greater scale, energy dashboards for progressive check and energy saving commitments and improving building envelopes are also very useful.

All energy saving measures start with individual and organizational-level commitment to save energy and protect environment. Building a team and assigning a leader for the team, informing the community with transparency regularly and arranging meetings with users to educate, inform and motivate them can be very effective. It should be kept in mind that success of all energy saving efforts and measures lie in human behavior and commitment. For instance, arranging a meeting with a small group of people in a small room or a warmer/already warmed room can save energy without any effort.

Biggest contribution to energy conversation comes from insulation including building envelope. A study done by Texas A&M University indicated that 80% of the energy savings are from building tune-up (U.S. Fish and Wildlife Service, 2003). Improving building envelope helps to lower energy loses in cold and even hot seasons. In the past, thermal loss mostly meant heat loss in cold climates or seasons. However, loss of cold air from air-conditioners has gained importance due to increasing use of them because of global warming. In addition to building envelope, door and window air draft insulation reduces energy expenditure.

It is clear that buildings with no obstacles of direct sunshine and sunlight will reduce amount of energy used inside. One measurement to be taken in the construction phase is that building windows on the north hemisphere should face the south while on the south the north to receive more sunrays. According to the research by Environmental and Energy Study Institute (2010), building tune-up including energy efficient building envelop, doors, windows and foundation may improve building energy efficiency by up to 50%. The same research showed that “lightly colored roofs” can reduce energy consumption for cooling by 40% in hot climate regions while dark colored ones can serve for the purpose in cold climate regions. In existing buildings, energy retrofit applications provide data on where the energy goes and what can be done to save energy or improve energy efficiency.

Installing a more energy saving lighting system, even only more efficient light bulbs, decreases energy expenditures in any type of building. For instance, according to the Qualified Light Bulbs 2009 Partner Resource Guide of U.S. Department of Energy Star (2009), a compact fluorescent light bulb of 13W produces enough lighting equal to the lighting of a 60W traditional (incandescent) light bulb. Moreover, it spends as low as a quarter of energy that an incandescent light bulb does. The same source counts the advantages of certified compact fluorescent light bulb (CFL) as payback period of seven months and $30 energy cost saving during lifetime. Likewise, T-8 tubular fluorescent bulbs use less energy than T-12 ones. However, higher technologies sometimes bring higher risks as compact fluorescent lamps are made of toxic mercury (mother nature network, 2011). Using solar powered lights, gaining advantage of solar lighting and smart windows also contribute to better lighting and thermal balance of the environment, consequently to energy saving in buildings.

Clean water delivery to residential and commercial customers and retreatment of wastewater that require electricity represent the largest energy expenditures by municipalities, and municipalities in U.S. annually spend 37 billion kWh energy meaning $3 billion a year to provide and treat water (Inner City Fund International, 2008). Thus, one of the effective and easy energy saving measures is saving water by fixing an optimum hot water temperature, using low-flow water taps and showers, installing low flush water closets and using washing (up) machines that spend less water. Additionally, smart thermostats allow users to adjust building temperature when it is in use.

Energy dashboards with measuring units and internet connection enable all energy users, for instance, in a school all administration, staff and all students, to monitor energy usage, to compete with others and build a commitment to save energy.

Sustainable Energy Authority of Ireland’s (SEAI) advisory report basically recommends insulating of hot water system and installing more advanced and energy efficient control systems (seai, n.d.a).

The following figures on building energy consumption are taken from The European Commission’s official website:

* + - Buildings in European Union consume 40% of overall energy use and accounts for 36% CO2 emissions.
    - Buildings over 50 years old sum up 35% of all the buildings and old buildings use 25 liter oil on average in a year while the average of recently built ones is less than 5 liter of oil a year (European Commission, n.d.).

These figures show that energy conservation and environmental issues are significant enough to deal with international legislations while individual and organizational efforts are crucial as well.

The European Union set forward the 2010 [Energy Performance of Buildings Directive](http://eur-lex.europa.eu/legal-content/EN/ALL/%3BELX_SESSIONID%3DFZMjThLLzfxmmMCQGp2Y1s2d3TjwtD8QS3pqdkhXZbwqGwlgY9KN%212064651424?uri=CELEX%3A32010L0031) as milestone legislation to lessen building energy consumption. The directive asks from the Union members to have all the new buildings to be nearly zero energy buildings by the end of 2018. Additionally, building rental and sale advertisements are to include energy performance certificates [(European Commission, n.d.)](https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings). Furthermore, the 2012 [Energy Efficiency Directive](http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1399375464230&amp;uri=CELEX%3A32012L0027) demands only energy efficient buildings to be purchased by the governments [(European Commission, n.d.)](https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings).

The European Union aims to lessen its internal conservatory gas releases by 80% by the year 2050 ([Szalay & Zöld](http://www.sciencedirect.com/science/article/pii/S0301421514004054), 2014, p.511).

## Energy Performance

## 2.2.1 Building Energy Performance and Ratings

Official Journal of European Communities describes energy performance of a building as “the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting” (Official Journal of European Communities, 2010, p. 15). The same official journal referring to Directive 2002/91/EC of the European Parliament and of The Council provides demands this calculated amount of energy to be displayed in numeric indicators. The main factors to be included in the measurement can be counted as transparency and solar exposure, climate, insulation, design, location, nearby constructions, self-energy production and IAQ (Official Journal of European Communities, 2010). Furthermore, Hu et al. (2012) assume that it will be more cost-effective to review energy use of a group of buildings in comparison with a single one.

Thus, building energy performance must be evaluated through some calculation to build necessary indicators and ratings. European Standard EN 15603 (European Committee for Standardisation, 2006, p.16) outlines the criteria to assess building energy use and methodology to estimate total energy rating of a building. Naturally a lot of buildings use different types of energy sources and the cumulative energy use is calculated in variety of energy units. While calculating overall/cumulative energy use, three impacts of energy use as primary energy use, carbon dioxide emission and national energy policy parameter are taken into consideration. In some cases, energy cost is also used as a display value. Corgnati et al. (2008) depicts building energy ratings (BER) as “the evaluation of the energy performance of the building based on the weighted sum of the calculated or metered use of energy carriers” (p.801-809).

Basically there are two types of building energy ratings;

* + - The Calculated Rating: It is achieved through calculation and estimation of all energy sources delivered.
    - The Measured/Operational Rating: It is achieved through measurement and estimation of all energy sources delivered.

Because it is achieved through calculation, the calculated rating can vary depending on calculation methods, occupancy and climate zone. Three basic calculated rating types are design rating, asset rating and tailored rating. The design rating calculates the energy rating of a building at the designing stage. The asset rating and the tailored rating are similar and both calculate the energy rating of a building after construction. The difference between them is while asset rating calculates BERs after construction with standard occupancy and climate data, tailored rating does so with actual occupancy and climate data. Calculated ratings can be most beneficial when the building is new, big or/and multi-faceted, and when occupants of the building change often. This type energy rating can be achieved according to primary energy consumption or on-site energy use. Most European countries use calculated energy rating for new, small and private buildings while they use operational rating for big and multifaceted non- residential constructions, and for the systematic assessment of public constructions

(IEA, 2010, p.12). Calculated energy rating states how primary energy is used for each unit surface space annually (kWh/m2/yr). A sample Building Energy Rating (BER) chart is given below in Figure 1.

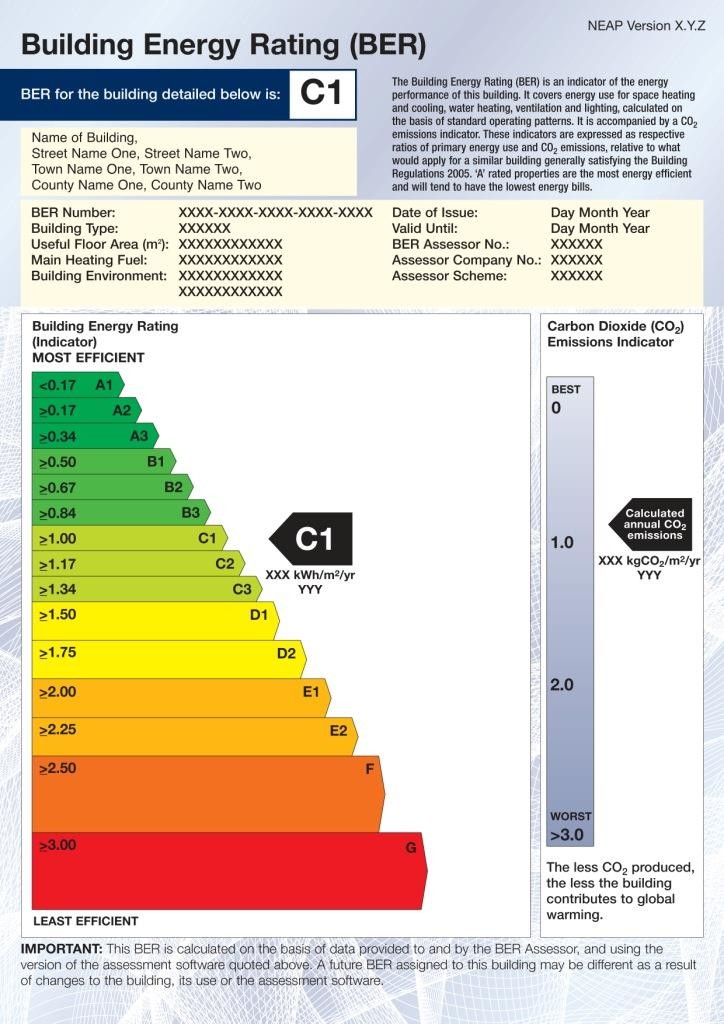


Figure 1. A sample Non-Domestic Building Energy Rating (BER) chart

(Source: seai (n.d.b) http://www.seai.ie/showImage.aspx?imgUrl=/uploadedfiles

/EPBD/ Non%20domestic%20BER%20web.jpg)

The measured rating can provide better data on a BER as it is not based on calculation but measurement of the energy used in a building. Measured ratings are also more applicable for building energy certificates.

The Ratings can be used while selling, renting, comparing, regulating or retrofitting, certificating or/and optimizing. It is clear that these two ratings cannot be matched because of the methods they are achieved. Yet, the difference between them can throw lights into the differences between calculated and operational energy usage of buildings.

Although it is not the concern of this thesis, energy efficiency rating and environmental impact rating are also worth mentioning. Energy efficiency rating is calculated according to the cost of energy use for each square meter floor area where environmental impact rating is calculated according to the carbon dioxide emission for the same unit area. However, it should be noted that Although, CO2 emission performances in OECD countries are better than in non-OECD ones, there is no substantial variance in energy performance (Zhou et al., 2012). Figures 2 and 3 below show samples of energy efficiency and environmental impact ratings for England and Wales.

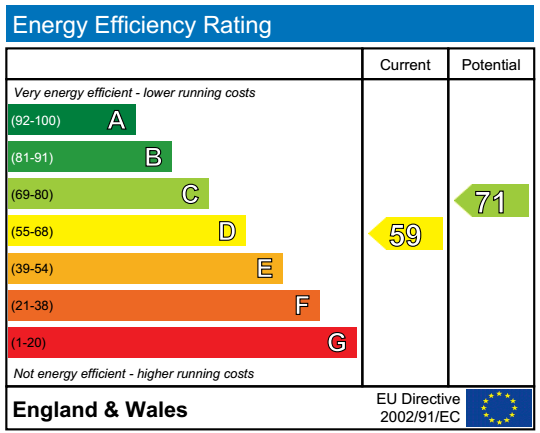


Figure 2: Energy Efficiency Rating

(Source: Department for Business, Energy & Industrial Strategy, 2005. p. 1. <http://www.energykey.co.uk/epcsample.pdf>)

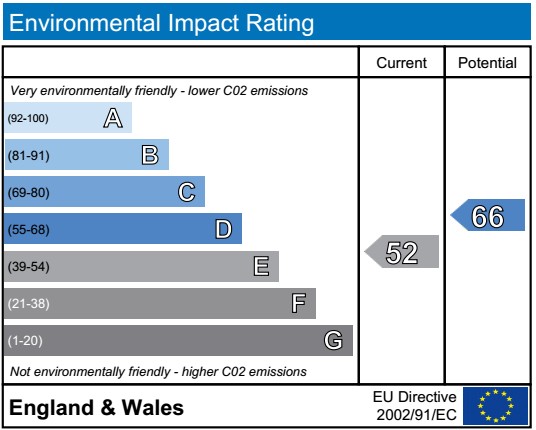


Figure 3. Environmental Impact Rating

(Source: Department for Business, Energy & Industrial Strategy, 2005. p. 1. <http://www.energykey.co.uk/epcsample.pdf>)

## Building Energy (Performance) Certificates

The Energy Performance of Buildings Directive (EPBD) through the Directive 2002/91/EC built the basics for energy efficiency in Europe. The European Parliament and of the Council of December 16th, 2002, declared all the existing and new buildings as the subject to building energy certification based on the Directive 2002/91/EC approved in 2003 (Official Journal of the European Communities, 2003). Dijk (2009) summarizes the targets of the directory to increase energy efficiency, consequently

performance, of buildings in Europe as:

* + - Building a calculation methodology framework for the building energy performance
    - Applying bottom energy performance prerequisites for new constructions
    - Providing building energy performance certificates
    - Checking air-conditioning and boiler system systematically
    - Setting standards for certification specialists and inspectors.

Although the EPBD provides a mandatory certification, members of the Union are free to choose the most appropriate procedures that fit themselves (Dijk, 2009). On the other side, energy performance certificates are not mandatory for some buildings such as places of worship or buildings that will be used for less than two years (GOV.UK, 2016).

Energy performance certificates are used to rate all types and sizes of buildings from the point of their energy performance/efficiency within proper users’ comfort and buildings’ ability to function. According to an official website by the United Kingdom (GOV.UK, 2016), an energy performance certificate covers:

* + - data on the assets energy performance and characteristic energy expenditures
    - recommendations to lessen energy use and expenditures

Except for the mentioned primary function, they can be also used for recommendation purposes on upgrading buildings and their payback while improving efficiency, users’ comfort, and saving money and environment. Energy performance certificates are given by accredited assessors that perform an on-the-spot energy survey in properties. Information gathered after the investigation is analyzed with the help of energy assessment software and the property is given an energy efficiency rating number and a value for prospective development. As schools are educational institutions and they are great in numbers, their energy performances are important factors for energy education and efficiency.

Since different variables such as equipment, climate, building design and construction, energy and water systems are used in certification process, building energy performance

assessment should be carried out - taking building codes that refer to standards into account by a proficient evaluator/assessor. For the new buildings under construction, certification is done to see whether the building meets the requirements of building codes while used to compare with similar buildings and assess energy saving opportunities as Home Energy Rating System (HERS) Index does in USA for the already existing buildings. Energy performance certificates for existing buildings can be demanded while purchasing or renting. The European Union Energy Performance of Buildings Directory (EPBD) requires it even when advertising buildings and energy performance certificates cannot cover a longer period than ten years (IEA, 2010). Another use of certificates is to allow building owners and prospective buyers to estimate the functionality of the building in comparison with others by using building energy codes from the point of energy efficiency. Similar to electrical gadgets, energy certificates also use A to G labelling system in the European Union while HERS is used in USA (IEA, 2010). For instance, a C-label building which can be an average building means that there is still a lot of progress to be carried out while labelling moves from A! to A++ to describe highly efficient buildings. However, mostly affirmative/positive labels demand to meet the bottom prerequisites of standards. For instance, average rating is in the range of D or E in most European countries (Department of Energy and Climate Change, 2013).

Building certificates can be obligatory as in EPBD in European Union or voluntary as in EnergyStar in USA. While voluntary certification is mostly applied by owners of highly energy efficient buildings, mandatory ones are used to find the least energy efficient buildings among many others to recommend energy efficiency measurements. Because they are applied to a large number of buildings, mandatory certifications provide more information on buildings in general although they are more difficult to apply and consequently cost more. Yet, mandatory energy certificates may help governments to imply more realistic energy policies and lessen energy consumption and CO2 emission. The success of certification does not only depend on providing it but also procedures taken afterwards such as empowering procedures and proper systems, training responsible people and sustaining the required functions and qualities.

In spite of all the efforts for efficiency, standards and certifications of energy ratings, efficiency and certification, there are still other concerns to build the best practice. One of them is insufficient number of buildings that follow the directory. A research in England and Walles showed that only 1/3 of the inspected buildings meet the requirements of the directory (Pan & Garmston, 2012). Furthermore, the English House Condition Survey (EHCS) showed that better energy rated houses frequently devour more energy than lower rated ones (Burman et al., 2014). Kelly (2001) recommends that financial inducements and behavioral approaches be employed to close energy performance gap that is the gap between optimum and real energy use. Following an energy policy as another measurement to close that gap will be imposed for all new buildings by the end of 2020 (The European Parliament and the Council of the EU, 2010). Some reasons behind this gap might be:

* + - The directory itself, possibly more notional than practical
    - The updates in directory as already existing buildings cannot follow updates easily
    - Problems caused by building design, construction and material
    - Lack of qualified assessors and appliers
    - Issues concerning modelling and methods
    - Lack of effective energy policies

In addition, historical buildings present difficulties for building energy certificates due to barriers to investigate their insulation quality and building renovation restrictions for historical buildings.

Display Energy Certificates (DECs) as an indicator for the actual energy usage of a building are also worth mentioning. They, complemented by an Advisory Report, are grounded on all the recorded energy consumption of a construction by all the varieties of energy resources and used as an operational rating to assess energy efficiency of a building. Display Energy Certificates rate buildings from A to G as well. From the point of CO2 emission, it is calculated in comparison with its type. Department for Communities and Local Government (2015) explains the criteria as below;

* + - If a building has zero CO2 emission, it is rated as zero.
    - If a building’s CO2 emission is representative/average of its type, it is rated as 100.
    - If a building’s CO2 emission is as twice as the average of its types, it is rated as 200.

## Energy Benchmarking

Energy benchmarking in general, non-domestic buildings’ energy benchmarking in specific is based on comparison between the target (building) and a successful sample and it is considered as a key means to increase building energy efficiency and transparency (Pérez-Lombard et al., 2009). The Construction Industry Institute (CII) (1995) defines benchmarking as a methodical process to measure and compare one’s performance with acknowledged frontrunners to enable better performance when modified and used. The break concerning the present state of the subject building and the best practice building as a sample and benchmarking reference provides the target improvement. Depending on the type of organization and its objectives, benchmarking systems use precise [indicator](https://en.wikipedia.org/wiki/Performance_indicator)s, such as cost, time or cycle time, productivity etc. per unit of measure (Fifer, 1989).

A very important notion in benchmarking is that benchmarking should be taken as constant process at different levels starting from the construction rather than a random one. Another important issue for benchmarking is that improvement of the system is the backbone of the process rather than personal and sectional ones. One of the greatest, if not the greatest, obstacle in front of benchmarking is institutions’ lack of knowledge of the importance of benchmarking or/and desire to implement it. For instance, benchmarking validation can be best achieved through the cooperation of an inside benchmarking unit and an independent and qualified outside team. Nevertheless, some organizations may resist to provide necessary information fearing that it will reveal their vital inside information or weaknesses. Readiness to compare and to compete with the others encourages companies for benchmarking. Ranking, regression and distribution models are the most commonly used benchmarking methods.

The most common indicator to be used as benchmarking tool is kWh/m2/year. KgCO2/m2/year as carbon emission and kWh/person/year as thermal comfort are also used. Choosing the right objectives and measures determined by success factors are vital for successful implementation (Kaplan & Norton, 1996). Basic concepts in benchmarking are measurement, comparison and development prospects. Having found out what causes the inefficient performance in comparison with the best one in the market, measurements

can be planned accordingly. Benchmarking can be divided into two categories as internal and external. While internal benchmarking is useful to compare operational processes with the desired ones mostly when there is no external best practice sample, the external one can be more fruitful to allow administrators to compare their progress and efficiency with their rivals to understand a more practical concept of what is considered as worthy. From another point of view, benchmarking can be sorted as;

* + - Process benchmarking that its business processes within their target with the best practice,
    - Performance benchmarking that evaluate the organization’s competitive place in comparison with the best practice in the market,
    - Strategic benchmarking: searching in how the best practices in other sectors work.

While considering benchmarking, organizations should first build a roadmap to follow. The following Figure 4 provides a sample benchmarking roadmap for organizations (Camp, 1989).

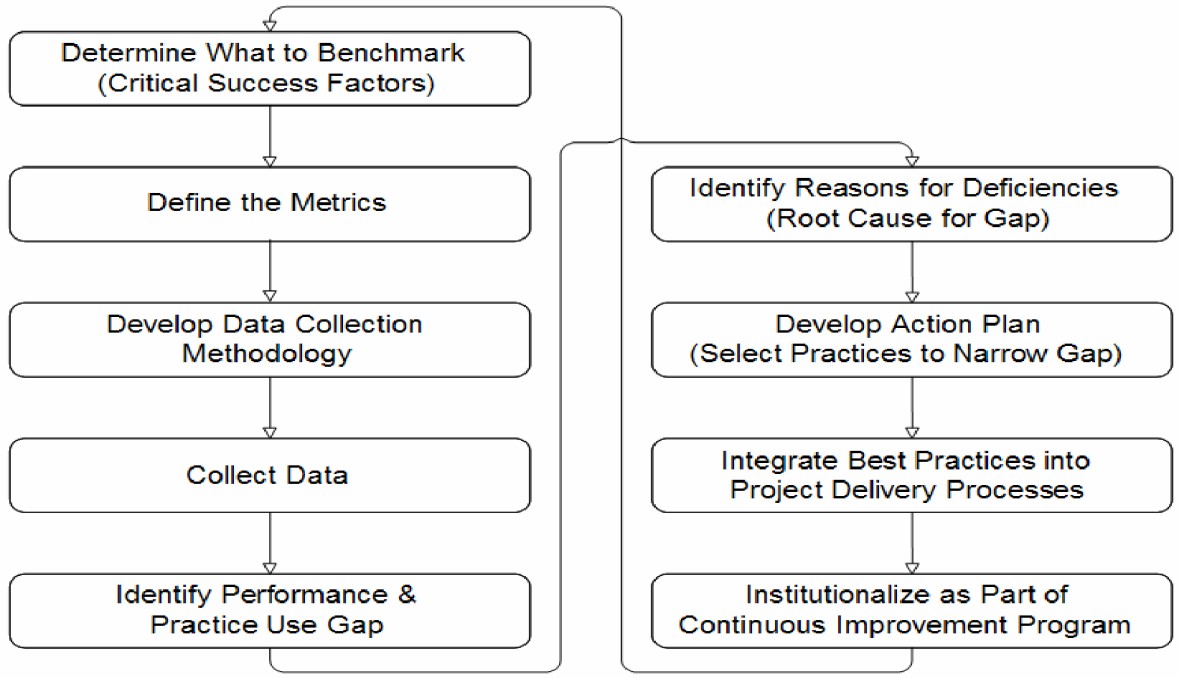


Figure 4: A sample benchmarking roadmap for organizations

(Source: Camp, 1989. Benchmarking, The Search for Industry Best Practices That lead to Superior Performance. Portland, Ore.: ASQC Quality Press.)

When it comes to the relation between energy performance certificates (EPC) and benchmarking, calculated EPCs do not have any direct relation with benchmarking (Pereira et al., 2013) as they are based on simulation and pre-calculation rather than comparison with the best practices. On the other side, benchmarking allows schools to compare their process and performance in comparison with best practices of similar schools under similar circumstances, such as primary or high school, climate, size, number of students etc.

Mandatory building ratings and labelling are carried out by EnergyStar in USA and EPBD in EU. The common point in all systems are that they use benchmarking as the key to evaluate the building energy performances and efficiencies making energy building benchmarking the initial step for building labelling (Borgstein & Lamberts, 2014). Borgstein and Lamberts (2014) also numerate building benchmarking methods as:

* + - Simple normalization,
    - Stochastic frontier analysis that splits “error variables from inefficiency factors” (p. 82)
    - Data development analysis that focuses on relative efficiency of an identical group of constructions.
    - Building performance simulation that attempts to cultivate an archetypal model of the subject building.

The drawback of data development and simulation methods is that they cannot be used successfully as a public benchmark. Stochastic frontier analyses are quite operative but their dependence on building features makes their implementation difficult.

## Energy and Schools

## 2.3.1 Energy Consumptions in Schools

Pereira et al. (2014) utter great importance on school buildings from the point of energy performance since they have a great responsibility from the point of educational purposes and indoor environmental quality due to the issues of students’ health and well-being.

School energy consumptions play a significant role on societies’ energy consumptions and energy bills in Europe (EU, 2008) and USA (Airaksinen, 2011). Districts in USA

spend almost $8 billion to run primary and secondary schools and around 30% of schools consume energy inefficiently.

Unlike domestic buildings, schools practise various activities owing to different subjects and skills that should be developed. Additionally, they have wider range of energy consuming appliances some of which consume much higher energy than any appliance at home. Furthermore, different activities may require different adjustments concerning energy consumption and students’ comfort. Consequently, it is possible to say that characteristics and factors that affect energy consumption of school buildings are complicated issues to deal with. For instance, according to Gallachoir et al. (2007) the energy demand behavior in universities is less predictable than other non-domestic buildings. Nevertheless, according to Chung and Rhee’s (2014) on-site-survey in universities, it is proposed that between 6% and 29% of energy can be avoided in the surveyed buildings.

On the whole, differences between real and predicted energy consumptions in buildings is about 30% on average although it can be as high as 100% in some cases (Poirazis et al., 2008). More accurate energy prediction models at design levels should play an important role to close the gap. Thus, it is understandable that collecting valuable data in proper intervals from different aspects of energy consumption is key factor to evaluate school energy consumption, efficiency and performance.

First of all, it should be calculated where energy goes. Naturally, biggest energy consumption is supposed to go for heating in cold seasons and regions, and for cooling in hot seasons and regions as thermal and indoor air comfort are imperative factors for students’ health, comfort and outcome. Although, technologically more developed schools are supposed to have wider ranges of energy consuming appliances and energy rates, energy consumption items can be categorized into headings. Figure 5 below provides school energy consumption percentages by items in the USA in 2012.

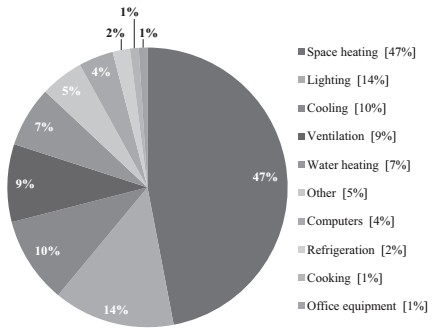


Figure 5: Average energy use profile of schools in the USA.

(Source: Pereira, L. D., Raimondo, D., Corgnati, S. P., Da Silva, M. G., 2014. Energy Consumption in Schools – A review paper. Renewable and Sustainable Energy Reviews 40 (2014);911–922.)

As seen in Figure 5, 57% of all energy goes for thermal comfort as space heating and cooling. Lighting comes as the second highest energy consumption and ventilation as the third. This type of information is very important also to differentiate thermal and electric energy consumptions. Some researchers, e.g. Jones et al. (2000) support the idea that thermal and electric energy consumptions must be analyzed independently. Moreover, the author of this dissertation, through his research, was informed that some schools specifically kindergartens in PCM use only electric energy for heating. Thus, different types of categorizing and calculating methods are needed to see same figures from different angles. It helps building managers, owners or school administrators where energy conservation opportunities lie and where energy conservation efforts fail. On the other side, total energy consumption figures can be useful for general benchmarking purposes (Bruhns, 2011).

However, above given percentages in Figure 5 represent US averages. They can vary due to types and functions of schools as boarding schools provide dormitories and dormitories mostly continue functioning 7/24 during an academic year. Energy consumption percentages in boarding schools specifically for space and water heating, cooking and refrigeration are expected to be higher than a usual day-time schools.

School energy performance can differ from benchmarks and the reason behind it may be some key factors affecting school energy performance. Energy Consumption Guide 73 (Government’s Energy Efficiency, 1998, p.4) according to a survey carried out in 1997 provides five key factors affecting school energy consumption as follows:

* + - Occupancy levels: Two of the benchmarking units for energy efficiency are energy used per students and meter square. Effective school space usage decreases the amount of energy used per student. Understandably, when the number of students decreases within the same building, the amount of energy per student increases as many school buildings are not designed to eliminate energy consumption in unoccupied spaces such as some classrooms that are periodically free of lessons.
    - Additional facilities: Supplementary facilities, for instance pools, canteens, gymnasiums and kitchens in specific (can lead to between 7 and 10% increase) will upsurge energy consumption. According to Energy Consumption Guide 51 of Department of the Environment, Transport and the Regions (1996), such facilities increase school energy consumption by around 20%.
    - Age of school: Although less emphasis is put on school age as a consumption factor and energy consumption of the same age schools can vary, newer schools perform better in general.
    - Hours of use: Extra curriculum activities and hours naturally increase energy consumption and this increase for every two hours is around 10%.
    - Size of school: Schools with the same school size and more than 400 students consume 25% less energy per student than with less than 200 students. It is

related to the student density. On the contrary, a bigger sized school with the same number of students will spend more energy than a smaller school with the same number of students. So, the best practice could be larger and newer schools with significant number of students.

Lo et al. (2012) state that users have an impact on building energy performance. Among several others, Masoso and Grobler’s study (2010) indicates that over 50% of the total building energy was spent during the non-working hours owing to users’ energy consumption behavior. For instance, energy users’ behavior plays an important role on energy consumption for building electric lighting (Dubois & Blomsterberg, 2011). Gul and Patidar (2015) consider electric lighting as a possibility to reduce energy consumption at realistic rates. Impact of users’ behavior on school building energy consumption is separately dealt in the section “Significance of Energy Users’ Behavior” of this dissertation.

Lara et al. (2015), supported with the findings of Antonini et al. (2009), claim that 1/3 heat loss in school buildings occurs because of building envelops. He also adds improper, badly managed/maintained, installed or oversized heat generators are causes of heat loss. In fact, heating systems consume almost 80% of all the energy used in some schools in cold climates and around 40% of reduction in energy conservation in such schools is feasible (Desideri & Proietti, 2002). Naturally, a suggestible solution could be to improve insulation and window glazing. Similarly, with the help of better insulation, ceiling fans and night ventilation, it is possible to save almost 30% in heating and 100% in cooling in hot regions (Dimoudi & Kostarela, 2009).

Central heating, HVAC systems that are often used in large buildings play a significant role on building energy consumption, indoor air quality (IAQ) and environment building (Wu et al., 2010) as the largest energy end use (Perez-Lombard et al., 2009). Thus, HVAC systems should be taken into consideration during school building design as one of the most important energy consumption factors and conservation opportunities.

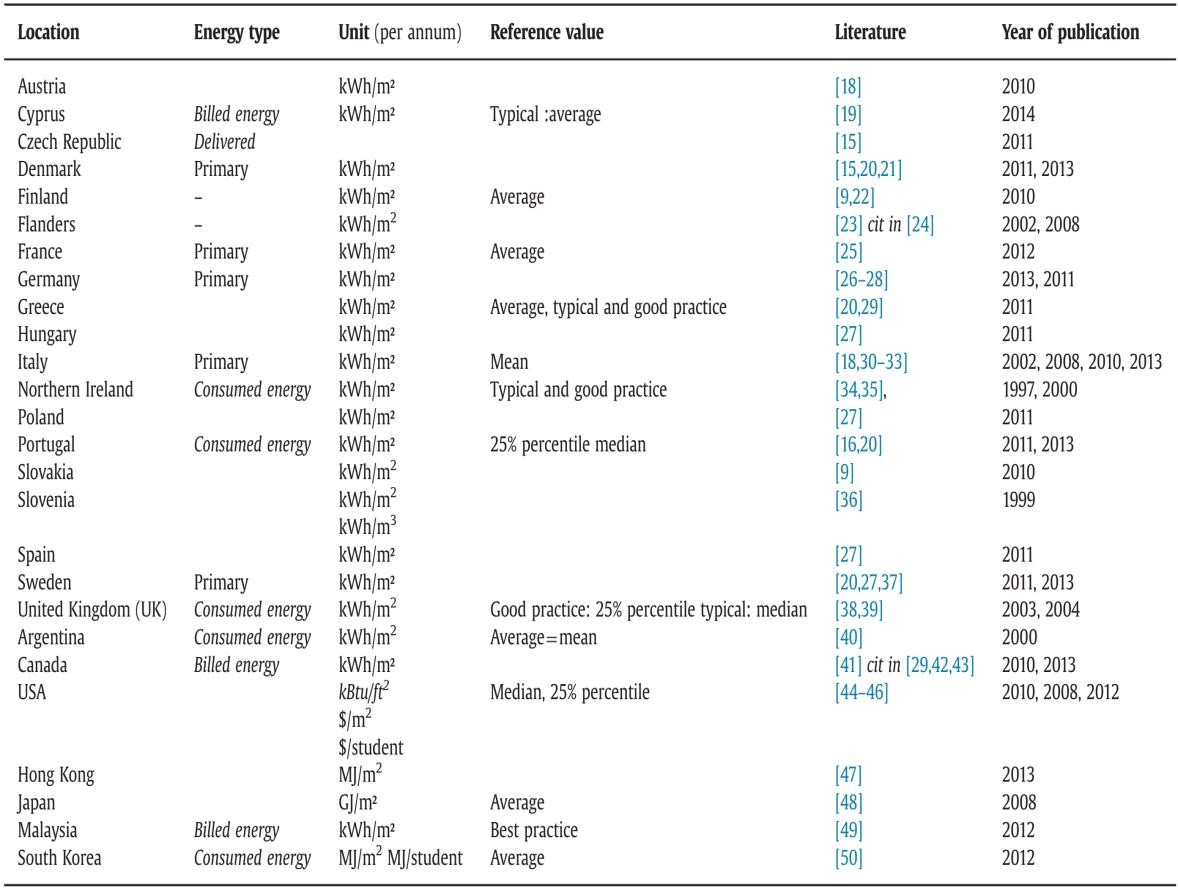
Sekki et al. (2015) claim that changes in building shapes including school buildings and increases in space volumes do not have any “clear impact on building energy consumption” because of varieties in usage hours, space and services. Additionally, Gul and Patidar (2015) claim that technological developments do not mean general decrease in energy consumption although they succeed in reducing energy consumptions of appliances.

Additionally, degree days based on climate, energy education at schools, the existence and practice of school energy policy, and efficiency of energy consuming appliances can be counted as other key factors for school energy consumption and performance. Starting from building insulation to developing energy efficiency and saving awareness, the concept should be taken as a whole, even though each measurement itself can significantly contribute to reduce energy consumption and students’ comfort.

Reduction in energy consumption will consequently lead to reduction in CO2 emission since buildings in European Union count for the 40% of total energy consumption and responsible for the 36% of CO2 emissions (Thewes et. al, 2014) and non-domestic buildings can reduce CO2 emissions by 70–75% (Green Building Council, 2011). For instance, in this manner, the UK aims to reduce her conservatory gas releases by 80% at minimum by the year 2050, comparative to 1990 levels (Department of Energy and Climate Change, n.d.).

As far as data characteristics that are used in school energy consumption are concerned, different countries use various data characteristics as energy type, measurement unit and reference value. However, according to Pereira’s et al. (2014) literature review on data characteristics used in school energy consumption, the most common ones are consumed and primary energy for energy types, kWh/m2 for measurement unit and average and typical energy consumption values for reference value. Table 1 below provides a summary of such data. It is worth mentioning that kWh/person/year could be used in researches specifically concerning students’ comfort levels.

Table 1: Comparison of data characteristics used in school energy consumption literature analysis



(SOURCE: Energy consumption in schools – A review paper Luísa Dias Pereira, Daniela Raimondo, Stefano Paolo Corgnati, Manuel Gameiro da Silva, Renewable and Sustainable Energy Reviews 40 (2014), 911-922)

## School Energy Consumption Figures and Benchmarks in Europa

Energy benchmarking, like in other building types, is supposed to enhance school buildings’ energy performances and reduce energy consumptions along with CO2 emissions. The amount of money saved from energy consumption could be used for educational purposes and developments.

Different measurement units are used for yearly energy consumptions and CO2 emissions. Most common ones are annual energy consumption per surface area (kWh/m2/yr) and annual CO2 emission per surface area (kgCO2/m2/yr). However, annual cost for $/m2/yr area ($/m2/yr) and for a student ($/student/yr) are also used (Stimmel & Gohs, 2008). Butala and Novak (1999) used annual energy consumed per unit volume (kWh/m3/yr) indicating the classroom heights may significantly vary and they can affect indoor environmental quality or energy consumption for the same indoor

environmental quality. Britain uses one thousand British thermal units (kBtu) and 1 kWh is equal to 3.412 kBtu.

Basically, there are two profoundly different approaches to examine school energy systems as top-down and bottom-up approaches. Hong et al. (2013) explains that;

* + - A top-down approach is based on building-level energy performance figures that deals with an outline of the system without specifics of sub-systems
    - A bottom-up approach implicates information and conditions of sub-systems to form a more accurate outline. For instance, benchmarks for schools develop by first assessing energy performance of separate systems, such as air conditioning. Then, that lower-level system information of energy consumption data is combined together to build a single Energy Use Intensity (EUI) to indicate a theoretical presentation of the school building.

However, it is a complicated task to build a school energy benchmark. Apart from approaches, schools should be categorized into groups depending on their types, structure, practice, energy demand and type, and climate zone to build a fair and accurate benchmarking system. In fact, there are already 29 existing benchmark classifications based on their activities (Hong et al., 2014) although they have similar usage, prerequisites (Bruhns et al., 2011). It is quite natural that different methods can be appropriate to depict different school groupings. For instance, multiple linear regression can be more applicable to assess the impact of building type and operative features on school energy consumption for benchmarking (Sharp, 1998), whereas Hawkins et al. (2012) find artificial neural networks (ANNs) more appropriate to evaluate energy consumption factors in university buildings.

Efforts to build benchmarking and certification systems are turning into first optional but later mandatory applications in developed countries. One of the practices of such systems is that they enable administrators to match energy performance of any construction with the typical and the best practice values of similar buildings. Despite the insufficient number of school buildings with DECs in the EU, public buildings that

cover more than 1000 m2 including nurseries, schools, colleges and universities are to

publicly display their energy performance certificates on a visible place such as front door or in the central building lobby from June 30, 2012 (Maldonado, 2013). However, the member countries are allowed to adapt legislations in accordance with their circumstances to save energy and reduce CO2 emission. For instance, Greece has previously defined three climate zones named A-C but then added one more, Climate Zone D (Pereira et al., 2014). Maldonado (2013) in his article, Implementing the EPBD

* presenting country reports 2012, provides the following examples:
  + In Belgium, the certificate covers all the energy resources collectively used for occupied areas based on the meters or bills. Development process is mostly planned on development of construction materials. The anticipated average

emissions and energy consumption for college and school buildings are 40 kgCO2/m2/year and 230 kWh/ m2/year.

* In the Flemish region, all repaired and new buildings have to realize prerequisites on Energy Performance (EP) (E-level) and 10 kWh/m2/year of renewable energy has been obligatory since January 1st, 2014.
* Cyprus is working in order to plan and build their first Nearly Zero Energy (NZE) schools.
* Slovakia sets school energy consumption reference value as Class D.
* In Denmark, schools can base their energy certificates on calculated or measured energy consumption according to a foremost revision to EPC in 2011.
* In Finland, maximum energy consumption value for schools and care center are set to 170 kWh/m2/yr.
* In Portuguese case, all repaired and new buildings are supposed to have B- energy efficiency label although there is not any particular regulation for school buildings.

In addition, in Czech Republic, Energy Label C is set as the minimum required category (Maldonado, 2011, p. 482) and in UK, according to Good Practice Guide 343 (The Carbon Trust, 2005), the representative and top practice standards for primary schools, respectively, are 157 and 110 kWh/m2/year (Hernandez et al., 2008). In the UK, electricity and fossil fuel consumptions are calculated separately for school benchmarks to see both school energy performances clearly (Nifes Consulting Group, 2003). Except for university campuses, data for more than 15,000 school buildings are filed and according to that database, school buildings are the second most carbon intensive buildings after hospitals (Bruhns et al., 2011). Finally, a major energy renovation program in all schools buildings which of half were built between 1880 and 1948 were taken place before March 2012 (Mairie de Paris, 2012).

Average school energy consumptions throughout the European countries differ. Some European countries and their annual school energy consumption figures in literature along with the research results of this dissertation are given in Figure 14 in “Conclusion” section.

Except for the European countries, in Canada, it is 472kWh/m2 although the Model National Energy Code for Buildings (MNECB) of Canada recommends 357 kWh/m2 as the average for the reference building benchmarking (Lemire, 2010).

One of the concerns about the average school or other building energy consumptions is that different researches in the same country may provide different results and some of those figures can significantly vary. Thewes et al., (2014) attribute it to sample size and selection, wide range of building types or only energy-efficient buildings, and they conclude that such figures should be regarded with caution. They also state that this fact explains the need of benchmark analysis to accentuate the types of examined buildings and boundary conditions.

## Energy Auditing in Schools

Energy consumption growth has become a crucial issue not only due to energy depletion of natural sources and increasing costs but also due to social and environmental concerns. Higher life standards demanding higher social and environmental quality and comfort are added to energy costs. Energy auditing along with energy benchmarking are of great importance for better energy efficiency.

In general, there are two ways to search for energy loss in buildings. The first one is to track building energy bills to see what has gone wrong and where. The second one is carrying out energy audit. Energy audit is a process of evaluating current state and taking measures to save energy and improve energy efficiency without causing adverse consequences, such as discomfort of workers and students. It can be done through as simple as a screening audit, also called walk-through audit, or a very complicated multi- facet analysis. Energy efficiency and cost-effectivity along with environmental issues are the chief concerns.

Despite variety in levels, an energy audit is basically supposed to respond to the following concerns:

* What is the present condition of the building and energy related equipment? (physical state, efficiency level, energy label, benchmark, energy bills)
* Where and what type of energy is used and wasted?
* What measures can/should be taken including people’s environmental comfort, need and cost-effectivity?

It is possible to prepare a list of energy conservation opportunities and rank their cost effectivities rather than simply make a list of energy consumption items. Regardless of the type of energy audit, it is vital to make a meticulous list of requirements, and a contract will assure owners, tenants or managers for a successful fulfillment. Energy auditing usually starts with benchmarking by using comfort, energy and/or energy demand indexes to compare the figures with similar buildings and to see the improvement later on. Screening auditing as a second and low-cost step enables to evaluate the current state and efficiency of the building, opportunities for further work. It includes reviewing energy bills, interviewing the personnel and walking through the building for an on-the-spot inspection. It provides rough calculation for investment and payback period despite being not a final decision.

Meticulous site energy auditing should be carried out by experts with a use of computer- based analysis followed by investments and modifications. Energy bills up to three years are collected to see usage profile. Short and long term energy consumption patterns should be analyzed along with better understanding of operating system through working with personnel. Measurements are taken into consideration in accordance with the financial analyses to meet owners’ investment criteria. Energy auditing softwares and platforms are of great help to implement energy site and specific system auditing, and to apply investment return and payback analyses. Investment-grade auditing based on engineering analyses provide thorough technical and financial aspects to balance investments and renovations. Pollution audits take two-year electric and fuel consumption figures into account to calculate air polluting emissions.

## School Energy Policy

## Significance of Energy Users’ Behavior

Users’ behavior affects energy efficiency (Salleh et al., 2015) and energy consumption patterns ([Heiskanen](http://www.sciencedirect.com/science/article/pii/S0959652612004416) et al., 2013) in buildings. Energy consumption analyses without taking energy users’ behavior will not be realistic as Masoso and Grobler’s study (2010) evidenced that energy is wasted in buildings even they are not occupied and according to Nguyen and Aiello’s (2013) citation one-third of that wasted energy can be saved with proper energy conservation behavior. It also applies to school buildings since users’ behavior can influence energy conservation up to 15% in schools (Ismail et al., 2009) indicating the importance of users’ behavior on energy conservation alone in school buildings. Salleh et al. (2015) draw attention to questionnaire surveys “on building users as respondents with the aim of investigating the relationship between user behaviors with building design in evaluating school building design” and observatory method on “user perception assessment in the building can provide information on the user performance and satisfaction level”. European Union’s goal to base energy consumption on users’ needs makes energy users’ behavior a more central issue. The challenge is that although energy efficiency is considered as the key indicator for energy consumption, it is not the same for the users. Except for simply saving energy in some ways, energy users should be able to understand and deal with the issue more conscientiously which requires knowledge of energy users’ behavior. After this

initial step, the case should be dealt from the point of improving energy users’ behavior and building designs accordingly. Optimum/Effective applications should be practiced that match energy efficiency – including users’ comfort and environmental issues -, users’ behavior and building design. Energy efficiency specialists should first understand users’ behavior (Parnell & Popovics-Larsen, 2005) as often building energy efficiency practices do not answer users’ demands and realities which limit the success of efficiency measures (Heiskanen & Lovio, 2010). Firstly, it is to be stated that energy use is the result of other purposes rather than simply the act of energy use. Thus, those concerns should be dealt with the help of various insiders, and more measurable and automatic systems. A good example taking users’ perception into account is Low Carbon Communities Challenge’s implementation in United Kingdom that observes energy users’ reaction to new energy conservation measurements (DECC, 2013). Naturally, involvement of students’ behavior in energy consumption in schools is limited in comparison with their behavioral impacts at homes. Yet, energy consumption/efficiency education at schools will help to develop better understanding of energy use and efficiency in every field and throughout life.

## School Energy Management and Policy

Growing school energy costs and bills make school energy management an alarmingly important issue. Likewise, climate change can alter energy policy as it introduces difficulties in in decision making (Baker & Solak, 2011). Starting from Stanley (1957) up to now researchers emphasized the importance, effectiveness, implementations of school policies, staff’s and communities’ involvement, effects of policy outcomes, interrelation between environmental issues and school energy policies, policy enactment and implementation, and the role of policy actors in policy (Lane et al., 2014). Organizations with energy management policies show better performance than the ones without (U.S. Environmental Protection Agency, 2005) and schools can save energy up to 25% through efficient management and school energy policies supported by distribution of information and guidelines (U.S. Department of Energy, 2009). Guide to Operating and Maintaining EnergySmart Schools (U.S. Department of Energy, 2009) by the U.S. Department of Energy counts the benefits of high performance schools as:

* Value to the Community: Quality schools attract businesses
* Educational Value: High-performing schools are educational tools to teach significance of energy efficiency to future generations
* Student/Teacher Health and Satisfaction: Indoor air quality, lighting and thermal comfort increases students’ outcome and attendances
* Operational/Financial: EnergySmart Schools reduce energy cost and are more systematic to run.

Environmental benefits due to less carbon footprints and depletion of natural resources should be added to the above-mentioned list. Lane et al. (2014) recommends two basic precautions based on energy efficiency as energy education and building a school energy policy. To harvest the best results, these two precautions should be combined or

* even better - energy education should be taken as an significant partition in school energy policy. Lane et al. (2014) also state that the Wisconsin K-12 Energy Education Program (KEEP), as “a statewide energy education program in Wisconsin to promoting the development of energy policy and education plans in the state's schools”, can be used as a guideline. The program does not only build a plan for the district but also provides a school energy program framework to be applied. Department for Education and Skills (DfES) (2002a) also delivers a guide to manage school energy and water. The guide summarizes energy management action plan in several steps as follow:
  + Identify current school energy management through a matrix
  + Display the current energy cost
  + Assess what and how to improve
  + Compare through benchmarking
  + Set realistic energy saving/efficiency objectives with low cost or no-cost implementations
  + Streamline school accommodation for the best efficiency
  + Sustain school energy and energy linked systems
  + Compute the economic energy costs
  + Instruct and train school members

A simplified energy management guideline by EnergyStar of the U.S. Environmental Protection Agency Program (2013) is given below in Figure 6:

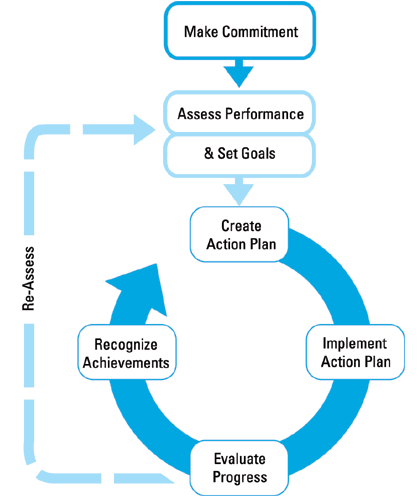


Figure 6: A simplified energy management guideline (Source: EnergyStar, 2013. Guidelines for Energy Management. p. 2.)

Inspecting successful samples and a detailed school energy policy matrix is a good start to build a school energy policy. For instance, KEEP can be very useful at least to have a practical guideline for a start. As an energy management matrix, the matrix by National Building Specification’s Energy Management Guide (1993) has been used directly or with some variations by various organizations, such as National College for Teaching and Leadership (National College for Teaching & Leadership, n.d.) and in the guideline called “A Whole School Approach” by Carbon Trust funded by the UK Department of

Energy and Climate Change. It is a five-level matrix with Energy Policy, Organizing, Motivation, Information Systems, Marketing and Investment as evaluating and development variables. Some organizations such as Wiltshire Council (Wiltshire Council, 2013) use “Training, Performance Measurement and communicating as variation. The lowest level is considered as “no explicit (energy) policy” and the highest one as “energy policy action plan and regular review have active commitment of top management as part of a corporate strategy”.

School energy education is an important part of school energy policy. Schools can arrange lectures, energy efficiency/performance information sessions and meetings, in- service trainings, science fairs, informative poster competitions etc. to attract students’ and staff’s attention to energy savings and efficiency, and prompt them to take more actions. On-the-walk school energy survey with students and staff can also serve for the purpose.

A sample primary school energy policy by Court Farm Primary School (2014) is given in Appendix B.

## Energy Consumption, School Environment & Students’ Comfort

Energy consumption in schools keep increasing due to some factors such as the use of more equipment of technology, ventilation systems owing to the global warming, more opportunities for education and raise in life standards. Moreover, Burgos-Jiménez et al. (2013) claim that there is an affirmative and substantial link between monetary performance and “environmental performance” (Burgos-Jiménez et al., 2013). Research results, for instance in Luxembourg (Thewes et al., 2014) and in Scotland (Dobson & Carter, 2010) support the notion. Consequently, energy consumption has become a student-comfort related issue and brought about several scientific researches on the

topic, as in Griffiths & Eftekhari (2008) and Pegas et al. (2011). As Lourenço (2014)

states this increasing relation also changes “energy consumption patterns”. One of the energy consumption related aspects is occupants’ comfort and satisfaction, and evaluation of dwellers' contentment towards IEQ is usual procedure to assess IAQ and thermal well-being (Fabbri, 2013). Frontczak and Wargocki (2013) point out through their literature review that IEQ affects efficiency, education and improvement. Furthermore, according to Bakó-Biró’s et al. (2012) investigation, poor ventilation drops memory and concentration. According to Boerstra and Froukje (2010) increasing number of evidences show that poor ventilation and improper thermal conditions in classrooms are partially responsible for the decrease in students’ learning performance and the increase in their absenteeism. Yet, it is difficult to say schools provide proper indoor environmental conditions at least on average. Wargocki and Wyon (2013) assert that elementary schools even in prosperous countries often provide worse environmental circumstances in comparison with office buildings.

The problem is not simply solved by consuming more energy since some researches show that even high energy consuming schools do not provide environmental comfort for students. For instance, in Slovenia 60% of students complained about the poor indoor air quality in their schools with the highest energy consumption (Butala & Novak, 1999). Also, Berner (1993) found a relation between inadequate care for school facilities and children’s unsatisfactory school results.

Today the concept of indoor environmental comfort mainly covers indoor thermal, visual, acoustic comfort and air quality. These four features of indoor environmental quality and consequently comfort interrelate with each other and can affect general interior well-being and energy consumption of the facility (Catalina & Iordache, 2012). Thus, energy efficiency, costs and students’ comfort should be handled together and it requires co-operation of different scientific and practical fields. Figure 5 in the section “2.7.1 Energy Consumptions in Schools” provides U.S.’s school typical energy usage outline and according to the figure, 80% of school energy consumption goes to space heating, lighting, cooling and ventilation as the four functions with the highest energy consumption percentages. These four functions of energy consumption are correlated with thermal and visual comfort and IAQ. These four concepts are explained in the following sections.

## Thermal Comfort

A human body’s thermal steadiness can be achieved if body temperature is balanced with the environmental heat to allow human body heat to dispel. Individual factors such as dressing and personal metabolic/mental state, and environmental factors such as surrounding temperature, ventilation rate, unfavorably cold or hot window and wall surfaces, humidity and mean radiant temperature on walls and other surfaces (Kamarruzzaman & Tazila, 2013) and body heat exchange can play a role on a person’s thermal comfort. Studies on occupants’ thermal comfort show that people in a thermally comfortable environment are more productive (Huizenga et. al., 2006) and healthier (Myhren & Holmberg, 2007). Wargocki and Wyon (2013) state that based on earlier studies thermal circumstances and children’s appropriate scholastic growth are strongly related.

One of the earliest researches concerning relationships between higher heats and students’ academic outcome was carried out by Holmberg and Wyon in 1969. According to their results, children’s performance in classrooms with a temperature of 27 and 30oC were as lower as 30% in comparison with the students’ performance in the classroom with a temperature of 20OC (Holmberg & Wyon, 1969).

ANSI/ASHRAE Standard 55 describes thermal comfort as mental comfort with the thermal surroundings and is evaluated by individual estimation (ANSI/ASHRAE, 2013) making thermal satisfaction the key objective in school building design (Haddad et. al.,

2012). According to Kamarruzzaman and Tazila (2013), several factors from temperature from electrical illumination to construction envelope can affect thermal satisfaction.

According to the ANSI/ASHRAE Standard 55 (2013), an average person at rest with a

* 1. m² body-surface area produces 1.71 Btu per hour and this average is called as ‘1 met’. A human’s metabolic rate can change between 0.7 and 2.0 (or above) met depending on the activity (s)he is involved. Along with ‘met’ as person’s thermal state, eating habits and body shape can also influence an individual’s metabolic rate and consequently thermal comfort (Szokolay, 2010, p.16-22). Furthermore, unfavorably low (< 20-30%) and high (> 60%) relative humidity can cause discomfort by affecting skin evaporation (Balaras et. al., 2007).

Although students spend 1/3 of their lives in schools and environmental conditions can affect their outcome more than adults in offices since they are more vulnerable to hostile environment, there are fewer studies on the environmental effects on students’ comfort and success (Wyon & Wargocki, 2006, p. 181-192). Yet, it can be derived from relevant literature that extreme conditions of temperature and humidity reduce students’ attention span (Zeiler & Boxem, 2009), and their work speed and manual skills decrease in colder temperatures rather than warmer ones (Levin, 1995). Increasing number of electrical ventilation systems opens a new area of research on the effects of new systems and mixed ventilation applications, along with the new school building designs. Unfortunately, thermal comfort in numerous naturally ventilated schools are below the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) standards (Kwok & Chun, 2003) and naturally ventilated buildings are usually colder in winters and warmer in summers than the buildings with HVAC systems (Frontczak & Wargocki, 2011). Elbayoumi et al. (2014) state that “the seasonal ﬂuctuation of ambient temperature and relative humidity and as a result the ventilation rate” can lead to sick building syndrome and reduce students’ acuity and output.

The two thermal comfort models, the adaptive model which can be more suitable for naturally ventilated buildings and the Predicted Mean Vote (PMV) which can be more appropriate for the building under thermal control, are often used for thermal comfort of buildings. PMV, constructed on four environmental variables as air temperature, air rate and moisture in the air and mean radiant temperature along with two individual variables as metabolic rate and dress insulation, takes the (indoor environment) predicted percentage of people dissatisfied (PPD) into account to calculate the mean comfort vote of occupants while the adaptive model places a key role on an individual’s adaptive behavior such as activity, clothing, position and outdoor temperature (Haddad et. al., 2012). PMV index establishes a seven-level temperature scale from cold to hot. According to the PMV and PPD indexes, an individual’s thermal balance/comfort is achieved if the body heat loss and body metabolic temperature are the same (PMV=0) (Conceiçao et al., 2009). The adaptive model, the indoor comfort temperature is correlated with regional climate and individuals in various regions can feel comfortable with different temperatures (Humphreys & Nicol, 1998).

When it comes to the standards, CBE Thermal Comfort Tool for ANSI/ASHRAE Standard 55, European thermal comfort standards EN 15251, International Organization for Standardisation (ISO) 7730 and Predicted Percentage Dissatisfied (PPD) directories can be used for thermal comfort analysis and calculations (Olesen & Parsons, 2002) although in tropic zones such as Malaysia building occupants can adapt to higher temperatures that are beyond the ASHRAE comfort zone (Hussein & Rahman, 2009).

## Indoor Air Quality (IAQ)

Hostile consequences related to poor IAQ on people’s health let alone children’s is obvious. Studies on IAQ and students’ comfort indicate that IAQ in numerous countries are below the satisfying levels and they, along with increasing number of students, are the primary reason for several illnesses such as communicable ailments and sick building syndrome (Daisey et. al, 2003). Additionally, poor ventilation is the cause of up to 20% of absenteeism (Clements-Croome et. al, 2008) and poorer students’ performance (Wargocki & Wyon, 2007a). On the other side, Bakó-Biró et al. (2012) displayed that better air circulations increased students’ performance of computer-based psychological diagnostic tests and writing that demand mathematical and linguistic abilities. Also, Satish’s et al. (2011, p. 574) test on people’s performance of decision making proved that at CO2 levels of 2500 ppm people’s decision making abilities become marginal or dysfunctional.

Children spending great amount of time at schools are exposed to different sources of pollution. Indoor Air pollutants can come from inside or/and outside which should be observed well in spite of use of a proper HVAC system because air pollutants include tiny particles such as fibers, dust, mold, bacteria, unfavorable gas molecules etc. Pollutants can vary according to time, season, location and societal issues. As classroom ventilation rates are poorer than the given standards and children’s metabolisms are more sensitive, they are more likely to suffer from long term consequences. Taking into consideration that increasing number of artificial ventilation systems are needed to be used in classrooms due to global warming, the issue is becoming more crucial. On the other hand, high quality of indoor air and outdoor air supply rates with more than 25 liters each second increase students’ accuracy and speed (Wargocki & Wyon, 2007b).

The ASHRAE Standard 62.1 (ASHRAE, 2008) in U.S., and EN13779 (European Parliament and the Council of the EU, 2007a) and EN15251 (European Parliament and the Council of the EU, 2007b) in European Union provide standards of favorable IAQ. According to the ASHRAE Standard 55-1992, comfortable indoor temperature should range from 20°C to 25.5°C, humidity between 30% to 60% depending on the season, air ventilation between 0.4 and 1.7 cubic meter a minute per person and finally carbon dioxide levels less than 700 parts per million (ppm) above ground levels (Pennsylvania Department of Health, n.d., p. 2-3).

EN15251 categorizes IAQ into 1200 ppm as low, 800 as moderate, 500 as medium and 250 as high quality (Jones & Kirby, 2012). It is understandable that these rates also depend on the number of occupants, room dimensions, individual motion and metabolism (Persily, 1997). Despite no specification for humidity in BB101, the U.K. construction guidelines declare that a two-hour period in twelve hours should not be surpassed with a relative humidity level of 70% throughout the warming period and the same goes as one hour with 90% relative humidity (Office of Disaster Preparedness and Management, 2006).

A lot of studies show that classroom air qualities are poorer than expected. For instance, Godwin and Batterman’s (2007) research results release that only 27% of classrooms have sufficient ventilation rate and Hellwig et al.’s (2009) research indicates that 47% of classrooms in the summer time and 89% of them in the winter time exceed 1500 ppm CO2 concentration. Along with many others, natural air circulation through windows were applied in most of these classrooms indicating that natural ventilation is not good enough for high indoor air quality, although the U.K. Government recommends natural aeration, if applicable, to lessen costs and ecological impact (DfES, 2002a).

To avoid consequences of low IAQ, air circulation amounts, temperatures, humidity along with CO2 concentrations should be adjusted according to international standards. The first step to solve the IAQ problem is to obtain necessary air quality data. Having collected sufficient data, the problem can be solved (to some extend) with proper HVAC systems. For instance, Jones and Kirby (2012) suggest top-down wind driven natural ventilation system which was installed in more than 1100 schools in U.K. and it improved the IAQ considerably.

Some other practical measurements can be counted as follows;

* + - Regular maintenance precautions
    - Source Control: not to bring needless pollutant to school
    - Eliminating pollutants before they are absorbed into school indoor environment, specifically air
    - Regulating duration, amount and pollutant site
    - Educating students on pollutants and classroom safety

## Visual Comfort

There are adequate number of researches and evidence that lighting in classrooms has effects on teachers and students. Preferences between natural daylight (Hathaway, 1983, p.28) or artificial lighting for better control on lighting (Lang, 2002) is debatable. While full band ﬂuorescent illumination can enhance acquiring (Lyons, 2002), Xue FJ. (2002) states that daylighting improves students’ performance and productivity, and enhance indoor environmental quality. Additionally, daylighting reduces general energy

consumption of a building. For instance, environmental shading from neighboring buildings can affect a building’s energy consumption up to 25–28 kWh/m2/yr (Li & Wong, 2007). These values may affect total energy need and energy peaks. It is also worth mentioning that only in the USA annual energy consumption for lighting amounts to between $15 billion to $23 billion (Lee et al., 2015).

Thus, a well-balanced integration of daylight and artificial one is the key as preferable levels of daylight is not always available. Recently growing interest in energy consumption is incorporating daylighting and electricity-based lighting to lessen energy consumption (Li & Lam, 2001). It should also be kept in mind that throughout technological and medical improvements better solutions can be found in the future. The correlation between lighting and children’s/students’ behavior and success may throw lights on sustainable educational success. According to Schreiber’s (1996) findings low illumination increases students’ interest and they become calmer.

Similarly, indirect diffuse of full spectrum fluorescent lamps reduces children’s maladaptive behavior (Shapiro et. al. 2001).

In comparison with ﬂuorescent lighting, incandescent lamps have an advantage that cooling of wires in incandescent lamps takes longer frequency modulation and does not change as fast as in ﬂuorescent lighting. While the standard AC supplies in Europa work with 50 Hz of frequency, this frequency in fluorescent lightings can reach up to

100 Hz (Chartered Institution of Building Services Engineers, Lighting Industry Federation (Great Britain), & Society of Light and Lighting, 2004) and despite being unnoticeable 100 Hz flickering frequency can have negative effects on visual comfort (Jaen et al. 2005). However, raising the frequency to kHz levels and using high frequency controllers can reduce headaches (Wilkins et. al., 1989), increase reading accuracy in spite of reducing reading speed (Küller & Laike, 1998), enhance visual search performance (Jaen et al., 2005). Thus, installing the proper ﬂuorescent lights can play an important role on students’ output. Likewise, flickers from other appliances such as computers can cause enlarged saccadic movements in response (Wilkins et al., 1989).

Chartered Institution of Building Services Engineers (CIBSE) (2004) suggests variant illumination levels between 300 and 500 lux on students’ desks depending on classroom design. Rea (1983) urges that illumination higher than 1000 lux causes discomfort for students where 300 lux is assessed as prerequisite illumination level (European Standard EN 15251, 2007).

Glare means visually brighter sight than the rest of the environment and it is one of the reasons that cause trouble for visual comfort of students. Strong lighting, close positioning to the light source and weaker background light can cause glare on students’ desks and consequently discomfort, even disability of sighting. Continual exposure to glare can even lead to headache and eyestrain.

Another reason for visual discomfort can come from projectors causing difficulties for students in perceiving images (Hall & Higgins, 2005) as well as reflection from white or smartboards, in particular when the surface is lustrous.

Improper pattern frequency, contrasting color stripes and the size of window blinds may also cause stress (Wilkins, 1995), headache (Harle et. al., 2006), and epileptic seizure (Fisher et. al., 2005).

## Acoustic Comfort

Sound is a function of vibration travelling as waves with various frequencies and when the sound waves hit a surface, alteration in sound direction and energy causes reverberation. Reverberation that is reflected sound from any surface will stay in until it is utterly absorbed or dissoluted. These reflections from a surface can interfere with students’’ auditory perception. Despite little variations, people’s hearing frequencies is between 20 to 20,000 hertz. However, when the frequency gets very low and high in the audible range, it starts causing hearing difficulties. For instance, when the sound frequency is lower than 500 Hz., it inclines to lead to unfavorable speech mask effects with consonants in particular and people with hearing challenge are more vulnerable to this effect (National Research Council, 2006).

Most teaching space activities depend on conversation between students and the teacher contributing great importance to the acoustic environment. Teachers are expected to deliver more student-oriented lessons and base their lessons more on practice rather than theory. Moreover, we are moving farther from the area of severely disciplined classes, schools and any educational atmosphere. Technology and the struggle to survive in the increasingly business-like educational atmosphere force educational institutions to use more and more technological gadgets that produce higher sound

pollution in learning environment. Not the last but another important issue is that global warming, higher level thermal systems and improving living standards demand HVAC systems that add to the distracting background noise in classrooms in more buildings and schools/classrooms (Nelson, 1999). Environmental acoustic noise, especially during social science lessons will not only impede students’ comprehension and consequently success level but also behavior patterns owing to lower attention and classroom discipline. It has been shown that students´ social behavior becomes calmer and the teachers experience lower physiological load (heart rate) as well as less fatigue with improved room acoustic conditions (Oberdörster & Tiesler, 2006).

Acoustic pollution seem to persevere in educational environments unless classrooms are acoustically designed, effects of acoustic pollution on young students’ learning abilities in particular are taken into consideration and if school administrations rely only on teachers and students for noise in classrooms. Nelson (2003) states that students with attention, reading, learning or hearing difficulties, students under 13, students using a language as the second one suffer more from the poor acoustic environment. Although teachers are also affected by poor acoustic conditions because increasing their voice may lead to some vocal diseases and fatigue, they should keep in mind that younger learners’ speech lucidity is lower than adults and acoustic environment of classrooms are to be build or organized according to younger students (National Research Council, 2006). According to the same source noise from neighboring places, echoing sounds, HVAC and outdoor noise are sources of acoustic pollution. Ceiling & Interior Systems Construction Association (CISCA) in its white paper ‘Acoustics in Schools’ (2009) adds that reverberation, unabsorbed sound waves from surfaces and ‘signal-to-noise ratios’ which are the lowest at the back of the classroom are other acoustic pollution factors. Building Regulations, School Premises Regulations and the Independent School Standards - Part E deals with aural environments in school buildings (Department for Education, 2015). The same section also demands design and construction of school

buildings to have appropriate aural environments and insulation to prevent disturbing noise.

The Independent School Standards and School Premises Regulations pay great attention to speech intelligibility and operational noise levels in schools and all the measured acoustic comfort values are to be in accordance with the speech transmission index (STI) in new and refurbished/existing school buildings. The regulations from nursery and community education to colleges of further education also cover:

* Equality Act for challenged students
* Teaching and non-teaching spaces
* New, refurbished/existing and temporary buildings
* Material changes of use

The following recommendations for the energy consuming items are supposed to reduce acoustic pollution and consequently improve students’ auditory perception in classrooms.

* Apply to international standards as much as possible.
* Locate and place energy-consuming and possibly noise-producing equipment such as printers, CD players and computers accordingly to reduce acoustic noise.
* Well-balanced and softly padded equipment will produce less vibration noise.
* Prefer fans with low velocities for less noise.
* Enclose instructional equipment with noise insulation near classroom areas.
* Keep HVAC, instructional and mechanical equipment as far as possible from listening/speaking activity areas. It should be noted that classroom speech intelligibility ratings in the United States are around 75% or less meaning that ¼ of verbal word is not comprehended (Seep et al., 2000).
* Prioritize natural ventilation systems when possible.
* Use insulation and plastic supports for the pipes, joints and other structural material to reduce vibration noise from the building.
* Take regular maintenance precautions for school equipment.
* Prefer quieter lighting systems in classrooms.

## Bases of the Hypotheses

Kosovo is the youngest independent country in Europe and she achieved a successful economic growth according to World Bank (2014). Although according to the same resource the growth percentage is expected to continue at around 4%, it presents “increased demands for electricity” with poor reliability as one of the main limitations for businesses in Kosovo making her depend on untrustworthy electricity importations (World Bank, 2014). For space and water heating purposes, the country relies on firewood and electricity that account for 80% of total heating consumption (World Bank

Groups, 2016, p.1-3). Although state schools’ percentage in all building sector was 3.75%, the total area of municipality school buildings in all Kosovo was 1690000 m2 and they covered 71.61% of all public municipality and 66.48% of all public central buildings in all Kosovo in 2013 (World Bank, 2014).

Kosovo decided “to adopt and implement selected EU energy *acquis*, including energy efficiency by signing the Energy Community Treaty, as Contracting Parties, in 2005” (Kogalniceanu & Raicevic, 2013). World Bank Groups (2016) counts Energy Performance in Buildings and Energy Labeling of Household Appliances as the major energy-related directives.

The key elements and potential changes in the Kosovo Legislative Framework as in World Bank Groups (2016) are given in Appendix C. As the legislations ask for energy efficiency action plans, Kosovo aims at 9% energy conservation by the year 2018 and

the aim was accomplished by 3% for the period 2010-2012 (The Government of Kosovo, 2013).

Having scheduled the first inclusive energy auditors’ training and energy auditing agenda in 2010, Kosovo implemented the 30 most attractive high energy performance projects in state buildings owned by municipalities supported by Western Balkan Investment Framework (WBIF) in 2011 and 2012 (Kogalniceanu & Raicevic, 2013). However, developing countries encounter more difficulties implementing energy efficiency measures. Kogalniceanu and Raicevic (2013) count main obstacles to improve energy efficiency as:

* + - High energy inefficiency in most consumption sectors
    - Low income
    - High public budget constraints
    - Severe influence of global economic crisis
    - Weak institutional framework
    - Incomplete legal and regulatory framework
    - Low energy prices.

World Bank Groups (2016) add low energy bill collection rates and higher than 18% thermal losses as the other factors in Kosovo although there is continual improvement. An Energy Efficiency Barrier Matrix for Public Sector by World Bank (2013) is also given in Appendix D.

According to World Bank Groups (2016) energy intensity of Kosovo in comparison with other countries is as given in Figure 7 below.

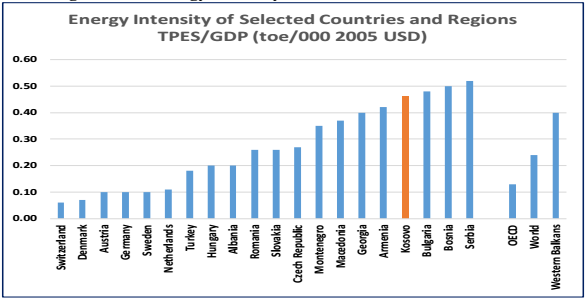


Figure 7: Energy Intensity of Kosovo and Other Countries

(Source: World Bank Groups. 2016. Kosovo: Options for Financing Energy Efficiency in Public Buildings. p.1)

According to Figure 7 above, the energy intensity of Kosovo (0.46 ([total primary energy](https://en.wikipedia.org/wiki/Total_primary_energy_supply) [supply](https://en.wikipedia.org/wiki/Total_primary_energy_supply) (tpes)/000 US$ General Domestic Product (GDP)) is much higher than those of the world (0.24) and The Organization for Economic Cooperation and Development (OECD) countries (0.13) although close to neighboring countries. In addition, Kosovo’s energy consumption per capita is 1.29 tpes which is around 31% of the OECD countries at 4.2 tpes per capita (IEA, 2015, p.1-33).

According to Energy Statistics of non-OECD Countries (2012) and Western Balkans Investment Framework (2013), although Kosovo produces more energy than Albania and Macedonia, she spends 40% less than Albania and around 33% less than Macedonia.

World Bank (2014) provides Energy Consumption by Sector in Kosovo in Figure 8 below and according to World Bank (2015) between 38% and 47% of energy can be saved in municipal buildings and the same figure can be up to 49% from the €24.3 million/year energy budget. World Bank (2015) also states that around 20-30% saving is possible only with energy efficiency measures. Furthermore, the payback period for cost-effective energy conservation practices for municipal and central government buildings is evaluated as between 4.9 and 5.3 years (World Bank, 2013).



Figure 8: Energy Consumption in Kosovo by Sectors.

(Source: WBIF. 2013. National Program for Energy Efficiency in Buildings for Kosovo: Financing and Delivery Options. Prepared by GreenMax Capital Advisors, Washington, DC.)

There have been efforts to increase energy performances of state constructions including educational ones in Kosovo, and Draft Final Report by World Bank (2013) - National Building Energy Efficiency Study for Kosovo summarizes these efforts concerning state schools as given below:

* + - Projects by West Balkans Investment Framework (WBIF)/KfW-2011/12) to apply methods to improve energy performances of state buildings provided energy audit results for 27 elementary schools, 4 high schools, 1 kindergarten and 1 dormitory in 7 municipalities (pp. 59)
    - “Study and Implementation of EE measures in Municipalities (63 schools and 2 hospitals), financed by EU (€15.6 m)” as the EU’s main energy efficiency project (pp. 71)
    - The GIZ project “Modernization of Municipal Services” (MMS) that was in application between 2006 and 2012. The project covered 56 energy efficiency projects including 31 schools (pp.72).
    - Training for Energy Auditors (Sept. 2009 – Sept. 2010) (pp. 73). A sample questionnaire to determine energy consumption in buildings by World Bank (2013) is given in Appendix E.
    - Public Awareness Campaign for Energy Efficiency and Renewable Energy Resources (Sept. 2009 – Dec. 2010) that covered The European Union pilot projects including 4 schools (pp. 73)

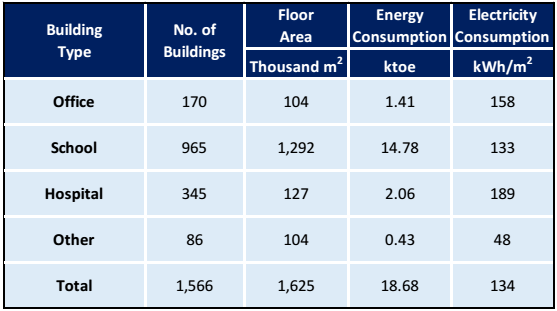
World Bank Groups’ (2016) publication titled as Kosovo: Options for Financing Energy Efficiency in Public Buildings about energy consumption in Kosovo provides one of the latest and most detailed information about the energy consumptions in Kosovo and the following information is summarized from the publication.

* + - There are 37 municipalities and they are responsible for energy consumption procedures in state buildings including schools.
    - Pristina has got the highest total building space with 200,000 m² out of 1.6 million m².
    - More than 50% of state buildings were built between 1970 and 1985. Thus, they are in need of urgent thermal insulation, efficient window glazing and efficient heating systems to provide users environmental comfort and to sustain their value. Draft Final Report of National Building Energy Efficiency Study for Kosovo by World Bank (2013) describes these buildings constructed before 1999 as buildings with relatively poor construction characteristics “supplied by boilers with efficiencies typically ranging between 60% and 65% using mostly coal and little

amount of oil”. However, heating systems started using more effective heat pumps/AC from the year 2000. In addition, improper type or quality of energy resource and poor building insulation are other major factors for inefficient energy consumptions in state schools. Again, according to World Bank’s (2013) Draft Final Report, 65.12% of total energy consumptions in public buildings were met by coal and 50% of electricity was consumed as heating during 2010.

* + - The mediocre electric energy usage for municipal buildings was calculated as 134 kWh/m² with a total 217,196 MWh costing Euro 15.8 million in 2013.
    - Pristina district heating network (Termokos) was completed in 2014 and it significantly reduced heating energy consumptions and fuel oil costs.
    - Schools, hospitals and offices are the main types of buildings in municipalities. Their average energy related figures are given in Table 2 below.

Table 2: Energy Consumption by Building Type in Municipalities



(Source: World Bank. 2015. Building Stock Study Kosovo: Feasibility Study of Energy Efficiency and Implementation Measures in Public Buildings in Kosovo, prepared by iC clean energy solutions GesmbH, Washington, DC)

According to the Table 2 above, offices and hospitals have the highest average electricity consumption per meter square. Although schools have got the highest energy consumption in total, their average electricity consumption is 133 kWh/m² and it is lower than those of other main types of municipal buildings. World Bank (2013) in its

Draft Final Report states that “at municipality level, the share of total energy expenditure on schools is 53.3%, on health service buildings 18.3% and is 11.7%, for other buildings.”

* + - Low energy consumptions in schools and hospitals may lead to users’ discomfort as their average energy consumption should be around 180 kWh/m² for schools and 255 kwh/m² for hospitals if they were operated in accordance with building standards (World Bank, 2015).
    - Firewood is often used in schools to reduce energy costs. Figure 9 below shows energy cost percentages by fuel types in municipal buildings.

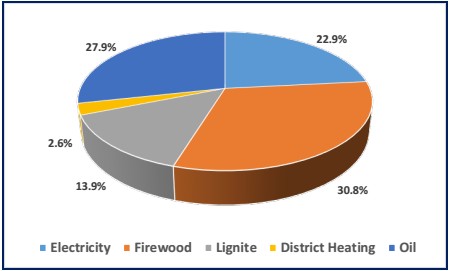
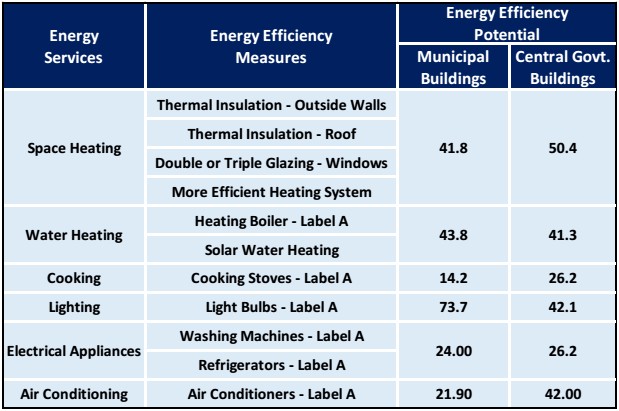


Figure 9: Energy Cost Percentages by Fuel Type in Municipal Buildings – 2013 (Source: World Bank, 2015. Building Stock Study Kosovo: Feasibility Study of Energy Efficiency and Implementation Measures in Public Buildings in Kosovo, prepared by iC clean energy solutions GesmbH, Washington, DC)

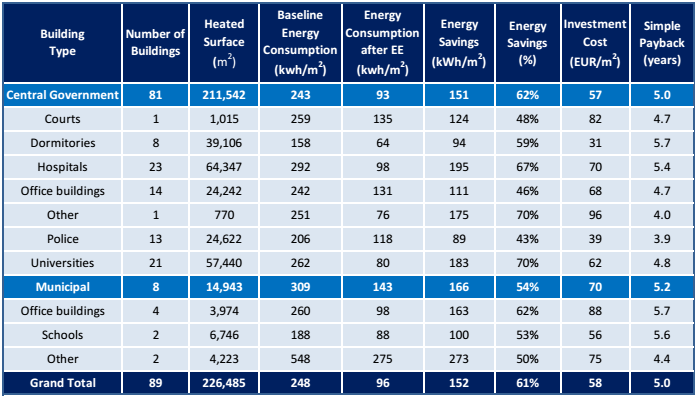
* + - The average energy consumption in Central Governmental Buildings is between 123 and 194 kWh/m² and these figures show that most of these buildings are not operated on the comfort level. According to national building standards, their consumptions should be between 166 and 262 kWh/m² with an average of 20° C indoor temperature (World Bank, 2015).
    - Heat and light levels in municipal buildings especially in municipalities outside Pristina are much lower than required.
    - There is a great energy saving opportunity in state buildings. Table 3 and Table 4 below provide information on “Energy Efficiency Measures and Potential Savings” and “Results of Energy Audits” conducted in the current World Bank project, respectively.

Table 3: Energy Efficiency Measures and Potential Savings



(Source: World Bank. 2013, National Building Energy Efficiency Study for Kosovo, prepared by Eptisa, Washington, DC.)

Table 4: Results of Energy Audits



(Source: World Bank Groups’, 2016)

According to Table 3, lighting, space and water heating present the highest energy efficiency potentials. Moreover, according to Table 4, schools can save 53% of their energy consumptions with an average of 5.6 years energy renovation payback periods. It will cost 56 Euro for each meter square of state schools with a total of 113.8 million Euros in all municipal buildings. The total investment will cost 156.2 million Euros

(World Bank Groups’, 2016). World Bank (2013) calculated the same investment cost as 66.99 €/m2 with a 4.6 year payback period and a total cost of 47 million Euros.

# CHAPTER 3

**METHODS AND PROCEDURES**

## Overview

Quantitative research methods were used in this research to determine:

* + - Whether a set of factors could affect energy consumption in schools and what the energy saving school features from the point of energy consumption are
    - Whether energy consumption affects students’ health and well-being

As Gall et al. (1996) state, the purpose of quantitative research is to deduce/draw conclusions about a large population using a small sample drawn from that larger population.

The research has got two stages;

1. Evaluating school energy practices,
2. Comparing students’ comfort levels between low energy consuming state schools with less building transparencies and compactness and high energy consuming state schools with higher building transparencies and compactness in Pristina Central Municipality.

The purpose of the first stage is to find out energy saving school features for the state primary and secondary schools in Pristina Central Municipality from the point of energy consumption. There are different factors as school features that affect energy consumption in schools. This research deals with:

1. Building age,
2. Study shift (morning or afternoon),
3. The number of school buildings,
4. Floor heights,
5. The number of school building floors,
6. Extra school buildings
7. The number of students,
8. Total school building area without extra buildings (m2),
9. Fuel type
10. Student density (student/m2)

as variables to measure/evaluate energy saving school practices for energy consumption per student and m2. However, the thesis builds hypotheses on study shift, number of school building floors and student density. Energy consumption per meter square as unit area is more often used for energy benchmarking practices. It should be noted that there

are three types of schools as pre-school, primary and secondary. Naturally, pre-schools tend to spend more energy per student as younger students are more vulnerable to undesirable/cold atmospheres. Pre-schools in PCM can also be considered as a separate division as they mostly use electric energy while primary and secondary schools mostly depend on fuel energy in state schools in PCM. This research takes primary and secondary state schools into consideration. Although not used for the comparison purposes, energy consumption per student and CO2 emissions per meter square were also calculated.

The purpose of the second stage is to compare students’ environmental comfort levels between high energy consuming state schools with more building transparencies and compactness and low energy consuming state schools with less building transparencies and compactness per student/yr in PCM. For the comparison, an English version of Örebro Environmental Study Questionnaire built by Örebro University Hospital in Sweden (Anderson, 1993) was applied to the students in the three lowest and the three highest energy consuming schools along with their building transparencies and compactness as additional sampling criteria per student in PCM according to the calculations from the first stage. The questionnaire uses a two-level Likert format as ‘Yes’ and ‘No’. It starts with ‘General Information’ questions to find out;

* 1. Whether students are sitting at the back or front of the classroom
  2. Whether students are sitting near the windows or the wall
  3. How many lessons students have already had

As to see if there are any differences between them from the point of comfort, the other sections of the questionnaire as given below.

* + 1. Health
    2. Well-being
    3. Other conditions
    4. Home conditions
    5. Environmental survey

## Research-Design

The research has two stages and it is designed to;

* + - Examine the energy saving school features by using yearly energy consumption per m2 as an indicator. The research design consists of data collected using a

table of school energy consumption figures and applying Manova, Person Correlation Coefficient and Spearman’s Rho Correlation analyses for the first stage.

* + - Compare students’ comfort levels in high energy consuming state schools with more building transparencies and compactness and low energy consuming state schools with less building transparencies and compactness per student by analyzing the differences in their responses to a questionnaire for the second stage. An English version of a previous study with the help of a questionnaire in a two-level Likert format consisting of 46 items built by Örebro University Hospital in Sweden (Anderson, 1993) was used. One-way Anova and Chi- Square tests have been applied for the second stage.

## Population

The population for the first stage was all the state primary and secondary schools in Pristina Central Municipality in Kosovo. There are 63 state schools in PCM including 13 secondary, 42 primary and 8 pre-primary schools. The pre-primary schools should be considered separate as their school structure and type of energy they use are different from the primary and secondary state schools. The state pre-primary schools in PCM mostly use electric energy while the others also use fuel energy. The pre-primary schools have not been included in this thesis.

The population for the second stage was the students of the three lowest energy consuming state schools per student along with their low building transparencies and compactness (MINECSs) and the three highest energy consuming state schools per student along with their high building transparencies and compactness (MAXECSs) in PCM to have a comparison between them from the point of students’ comfort levels through the Örebro questionnaire. For the academic year 2014-2015 when the researches were carried out, total number of the students in the three maximum energy consuming state schools was 2018 and in the three minimum energy consuming state schools was 4142.

## Sample

To collect the sample, the institutional contact with the PCM was used as the municipalities are responsible for the educational budgets. For the first stage of the research, all of the 55 state primary and secondary schools with a population of 45304 students in PCM for the academic year 2014-2015, without any exception, were included in the sample. All the population was needed to calculate annual energy consumption per student and m2, and CO2 emission per m2 as the first stage purely based

on arithmetical calculations.

For the second stage, three criteria were applied for the selection of survey schools. They were;

1. Annual school energy consumption per student,
2. School building compactness as ratio of building surface area/building volume,
3. School building total window size/wall surface size ratio.

The students of the three lowest energy consuming state schools per student with less school building window size/wall size ratio as a simplest building transparency measurement and school building area/volume ratio of compactness and the three highest energy consuming state schools per student with more school building window size/wall size ratio and school building area/volume ratio of compactness in PCM, chosen according to the first stage and additional calculations of compactness and transparency, were sampled to apply a students’ comfort questionnaire. Building compactness ratio is a decisive factor for building energy loss/gain. It is advisable to keep the ratio as small as possible in cold regions to prevent from heat loss and in hot regions to prevent from heat gain. However, due to global warming climate is becoming milder in cold regions and it can serve for the purpose for Pristina region as well. Additionally, higher ratios of window/wall sizes can add to students’ visual comfort. As seen from Table 5 below, the maximum energy consuming schools per student also have higher building compactness and window/wall transparency ratios than the minimum energy consuming schools per student.

Table 5: Features of the three MAXECSs and three MINECSs per students

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **SCHOOL** | **ANNUAL ENERGY CONSUMPTI ON PER STUDENT**  **(kWh/ST/YR)** | **Building Compactness (A/V)** | **Building Transparency (window/wall)** |
| **Maximum Energy Consuming Schools per Student** | 7 Shtatori | 1371.9 | 0.42 | 0.30 |
| Alauddin | 826.6 | 0.38 | 0.49 |
| 28 Nentori | 522.4 | 0.41 | 0.32 |
| **Minimum Energy Consuming Schools per Student** | Hoxha K. Prishtina | 349.9 | 0.36 | 0.17 |
| Sami Frasheri 2 | 264.6 | 0.37 | 0.23 |
| Sami Frasheri 1 | 163.5 | 0.37 | 0.15 |

The photographs of the six schools along with their satellite views are given below in Figure 10.



Figure 10: The photographs and satellite views of the six MINECS and MAXECSs

An



Figure 10: The photographs and satellite views of the six MINECS and MAXECSs (continued)

English version of the Örebro model and the MM questionnaire built by Örebro University Hospital in Sweden (Anderson, 1993) was used for the survey. For the academic year 2014-2015 when the researches were carried out, the total numbers of the students in the three maximum energy consuming state schools (MAXECSs) was 2018 and in the three minimum energy consuming state schools (MINECSs) was 4142. For the accuracy of the research data, 95% of confidence level, +/-5 of confidence interval of +/-5 points and 50% population proportion were applied. The calculated sample sizes needed were 323 in the MINECSs and 352 in the MAXECSs. The aim was to cultivate a valid sample covering at least 352 participants from both MAXECSs and MINECSs per student although according to Krejcie et al. (1970), a sample size of 370 is adequate for a population size of 10,000 to provide rational promise to replicate the same results. As a result, 352 valid samples in MINECSs and 360 valid samples in MAXECSs were collected to be used in calculations. An online interactive sample size calculator by Creative Research Systems (n.d.) was used to confirm the necessary sample size for the survey. Participants were proportionally drawn as the numbers of the students in schools vary. It must be noted observed that all MAXECSs and MINECSs per student were chosen among the state secondary schools in PCM. Simple random sampling method was used to ensure that the exploratory groups included approximately the same mix.

## Instrument

For the first stage of the research, the instrument to find out energy saving school features from the point of energy consumption per unit area was a table with the all necessary information including school features as mentioned in the Methodology Overview and their energy consumptions that were provided by PCM. Table 6 below gives school and energy consumption figures as a sample.

Table 6: School and Energy Consumption Figures as a Sample

**)**

**M (**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SCHOOL** | **TYPE OF SCHOOL** | **STUDY SHIFT** | | **BUILDING YEAR** | **NUMBER OF BUILDINGS** | **NUMBER OF BUILDING FLOORS** | **NUMBER OF STUDENTS** | **TOTAL ONE FLOOR AREA (m2)** | **STUDENT DENSITY (ST/M2)** | **FLOOR HEIGHT** | **EXTRA BUILDING**  **& ITS SIZE (Sports** | **hall, canteen, etc.)** | **KWATTS OF ELECTRICITY** | **LITRES OF OIL** | **WOOD (M3)** | **AVERAGE**  **kWh/person/year** | **AVERAGE**  **kWh/m2/year** | **AVERAGE**  **CO2/m2/year** |
| **MORNING** | **AFTERNOON** |
| **Sample** | **Primary** | **Yes** | **Yes** | **2010** | **1** | **3** | **651** | **2294** | **0.09** | **3.5** | **550** | | **41290.2** | **5000** | **0** | **146.2** | **13.8** | **5.3** |

For the second stage, a students’ comfort survey by the "Örebro model" and the MM questionnaire built by Örebro University Hospital in Sweden (Anderson, 1993) was used as an instrument to evaluate and compare students’ comfort levels in their classrooms. The MM 060 SP1 questionnaire used for students was refined with the help of the method developed by Jerkø et al. in 2006. It is based on Örebro model as well but a simplified version for students.

The questionnaire consists of 46 questions including 35 questions directly related to school including two questions about students’ location in the classroom and one question for the number of the lesson that students have already had. There are 12 questions about students’ health (How are you today?), 19 questions about their well- being (What is it like in the classroom today?), 5 questions about other conditions such as ‘Have you eaten anything today?’ and ‘ Do you have asthma?’, 6 questions about home conditions in a two-level Likert format, and one environment evaluation survey question with four options. The results of the questions under the category “Home conditions” and “Other conditions” were neither stated nor commented in the dissertation, although calculated, since they are not directly related to conditions in schools.

## Data-Collection

For the first stage of the research, data were collected through institutional contact. Ziyaddin Gashi, an advisor on education and a retired official inspector, was assigned to act as the institutional contact. Table 6 in Instrument section was sent to the Directory of Education in PCM via email and received in the same manner with all the required information for the first stage along with the information of the six schools about their building transparencies and compactness for the second stage of the thesis research as sampling criteria.

For the second stage of the research, through the same institutional contact, the school headmasters were informed about the research and asked permission to visit their schools to deliver and collect the survey. All the directors welcomed the request without any further requirement. 1000 copies of the questionnaire were printed as the total number of the target participants was 800 with an aimed sample size of 700 students. All the six schools, three schools with the minimum annual energy consumption per student and three schools with the maximum annual energy consumption per student, were visited by the researcher and his colleagues as instructors together in the last week of April 2015. All the instructors who helped the researcher during the application were Albanian who also spoke English well. The purpose of the survey and instructions were explained to the headmasters once more and they themselves, if vice-principles were not available, were asked to accompany the researchers and the instructors to make students be more aware of the seriousness of the application. Classes were visited one by one with at least two instructors. The purpose, importance and instructions were explained to the students in their own language. Students were also informed that the questionnaire did not require their identity, the information collected through the questionnaire would be confidential and would only be used for the research purposes. The first three questions of the questionnaire do not require personal ideas or feelings as they ask students about their location in their classrooms and the number of the lessons

they have already attended. These three questions were answered together with the help of instructors. Students were asked not to communicate during the rest of the questionnaire completion as they were supposed to express their own ideas or feelings. The instructors were allowed to help students if they could not understand anything about the questionnaire items. Paper-based questionnaires were collected by the researcher and the instructors and all the information was transferred to a Microsoft Excel database. Papers with missing response(s) were eliminated. 352 questionnaire papers from MINECSs and 360 from MAXECSs were accepted as valid for the calculations.

## Data-Analysis

For the first stage of the research, the energy consumption figures and affecting factors as given in Table 6 were added to Microsoft Excel database to calculate differences as percentages to calculate and see if there are any differences between school types/levels as state primary and secondary school, students’ shift as morning and afternoon, building age, number of students, number of buildings, total school building area (m2),

number of school building floors, floor heights, extra buildings and their sizes, the number of students, energy type and student density (st/m2) from the point of school energy consumption. An interactive program from the official website of The Sustainable Energy Authority of Ireland's (SEAI) (seai, n.d.c) was used to convert

oil and coal into kilowatt energy to find out the total school energy consumption. According to the website, energy conversion equivalences are as given below:

* + - A liter of heating fuel = 10.7826 kwatt
    - A ton of coal = 7734 kwatt

Wood is sold as in loosem3 in Kosovo and the net caloric value of a m3-loose-oak with an

average of 30% water is equal to 1034 kWh (Krajnc, 2015). Finally, the total annual energy consumption and CO2 emissions per m2 along with the total annual energy consumption per student were calculated. Having found out the annual energy consumptions and carbon emissions of the state primary and secondary schools in PCM per m2, the research aims to compare school energy consumptions according to the school feature variables to find out the percentage differences and consequently energy saving school features. However, according to the brief evaluations, the average school energy consumptions and carbon emissions are below the averages even in EU countries mostly due to the central heating system called Termokos. School energy consumptions and CO2 emissions were analyzed with the help Word Excel worksheet under the subcategories given below:

* + - School Type: primary (42 schools) and secondary (13 schools)
    - Students’ Shift: morning (25 schools) and morning + afternoon (30 schools)
    - Building Year: between 1936-1969 (18 schools), 1970-1999 (the period of mass construction) (22 schools) and 2000-2013 (15 schools)
    - The Number of Buildings: 1 (45 schools) and 2 or more (10 schools)
    - The Number of Floors: 1 (22 schools), 2 (17 schools) and 3 (16 schools)
    - The Number of Students: 1-500 (19 schools), 501-1000 (15 schools) and 1001+ (21 schools)

 Total School Area (m2): 1-1000 (9 schools), 1001-3000 (9 schools), 3001-5000 (4

schools) and 5001+ (33 schools)

* + - Floor Height (m): between 2.7-3 (12 schools) and 3.2+ (43 schools)
    - Extra Building: yes (33 schools) and no (22 schools)
    - Energy Type Used: electricity + oil (37 schools) and electricity + wood (18 schools)
    - Student density: 0.01-0.2 student/m2 (43 schools) and more than 0.2 student/m2 (12 schools)

In addition, as building carbon emissions is a significant factor in building energy regulations and saving environment, the state school building carbon emissions in PCM

were also calculated to find the averages. An interactive program from the official website of Carbon Footprint Ltd. (n.d.) was used to convert all types of energy resources into kgCO2 emission to find out the schools’ annual carbon emissions per meter square. According the Carbon Footprint’s website, the following conversion measures given below are used to find out carbon emissions.

* + - 1 kWatt electric energy = 0.53 kg CO2
    - 1 liter of heating oil = 2.97 kg CO2
    - 1 ton of coal = 2420 kg CO2
    - 1 ton of oak tree = 50 kg CO2

The aim of the second stage of the research was to find out the complaint level differences in the MAXECSs and the MINECSs per students in PCM with the help of Word Excel worksheet. First of all, three schools with the highest energy consumption and three schools with the lowest energy consumptions per student according to the first stage of the research along with their building transparencies and compactness were found out. Although an exact English version of Örebro survey was applied in those schools, items under the sections “Other Conditions”, “Home Conditions” and “Environmental Survey” were not taken into consideration when calculating the averages as they are dealing with home conditions and there are already some items concerning indoor air quality.

The items with the highest and lowest complaint percentages in both the MAXECSs and the MINECSs with their building transparencies and compactness were found to see the differences in students’ complaint levels and their percentages to compare both groups of the schools. Then, the items with the biggest differences between the two groups of the schools were found out. The research also analyzes the differences by calculating the average complaint level percentages and the highest complaint level percentages separately in both schools among the subcategories. Then, the items with the highest complaint level differences between two types of the schools were found out. For instance, the items with the highest complaint level differences between the students having the first and last three lessons were found out separately in both the maximum and minimum energy consuming state schools in PCM. The item with the highest complaint level difference by 24.8% between the students having the last and first three lessons in the MAXECSs was found out as Item 4 (Are you tired?) whereas the highest one by 33.6% in the MINECSs was Item 5 (Does your head feel heavy?). Then, the average complaint level differences were found out for the both types of the schools to compare the complaint gaps for the last and first three lessons between the two types of schools. The average complaint level difference for the last and first three lessons in the maximum energy consuming state schools was calculated as 6.7% meaning the students had higher levels of complaint in the last three lessons. The same average was for the minimum energy consuming state schools was 1.3%. Finally, the items with the highest complaint level differences for the last and first three lessons between the groups of the schools were found out. For instance, the biggest difference for the last three lessons was found out as Item 18 (Do you feel cold in the classroom in WINTER?) and for the first three lessons was found out as Item 27 (Is there distracting noise outdoors?) between the two groups of the schools. The same calculation and comparison method was applied to all the subcategories. The subcategories are given below.

* + - Having the last and first three lessons
    - Sitting the wall and window side of classrooms
    - Sitting at the back and front of classrooms

Furthermore, the research compares the average complaint percentages of the subgroups given below to compare between the two groups of the schools.

* + - Students having the last three lessons and sitting near windows at the back of their classrooms
    - Students having the last three lessons and sitting near windows in front of their classrooms
    - Students having the last three lessons and sitting near the wall at the back of their classrooms
    - Students having the last three lessons and sitting the wall in front of their classrooms
    - Students having the first three lessons and sitting near windows at the back of their classrooms
    - Students having the first three lessons and sitting near windows in front of their classrooms
    - Students having the first three lessons and sitting near the wall at the back of their classrooms
    - Students having the first three lessons and sitting near windows in front of their classrooms.

Finally, the highest differences in the average complaint percentages within the same group of the schools and between the two groups of the schools were found out. This calculation also allowed the researcher to find out the most and least comfortable subdivisions of students in two types of the schools. For the last, the research compares the total complaint percentages of the two groups of the schools.

For the analyses of the research hypotheses, the significance level was chosen as 5% (0.05) for a 95% confidence rating. For the first stage of the research, schools with double shift, multi-floors and higher student density were expected to have lower annual energy consumption per unit area than the central municipality average for the hypothesis 1. In addition, when the attended number of lessons increase, students in MINECSs in PCM were expected to have higher levels of problems concerning health

than the students in MAXECSs in PCM since children’s performance in classrooms can be effected by 30% with a temperature change of 10oC (Holmberg & Wyon, 1969) and poor ventilation is the cause of up to 20% of absenteeism (Clements-Croome et. al, 2008). Manova Calculator of SPSS was used for the *p*-value calculations at p<0.05 for a 95% confidence rating to determine if there were a statistically significant differences between the variables for the hypothesis 1, Pearson Correlation Coefficient and Spearman’s Rho Correlation tests were used for Hypothesis 2 and Chi-Square and one- way Anova tests were used for Hypotheses 3, 4 and 5.

# CHAPTER 4

**RESULTS AND DISCUSSION**

## 4.1 Results

It is worth mentioning that the research covers only the state primary and secondary schools in Pristina Central Municipality for both the first and second stages. In addition, the state schools in PCM have been provided hot water with Pristina district heating network (Termokos) since 2014 and it significantly reduces heating energy consumptions and fuel oil costs (World Bank, 2013). It may also affect students’ comfort levels.

## 4.1.1 The First Stage

The state schools in PCM do not use coal that greatly increases energy consumption and CO2 emission for heating while state schools in other municipalities use it as a means of heating. It considerably distinguishes the energy consumption and CO2 emission averages of the state schools of PCM from the rest in Kosovo. The average of all the state schools in Kosovo was calculated as 161.6 kWh/m2/yr in 2012 (World Bank, 2013) while only electric energy consumption was 133 kWh/m2/yr in 2014 (World Bank, 2015). However, the same average for the state schools in PCM was calculated in this dissertation with the help of information provided by the Municipality as 69.4 kWh/m2/yr in 2014. Thus, the author of this dissertation also calculated the energy consumption and CO2 emissions for the state schools in Vushturi Central Municipality

to compare both. The energy consumption and CO2 emission averages for Vushturi was calculated as 176,7 kWh/m2/yr and 48.4 kgCO2/ m2/yr, respectively. The comparison is summarized in Table 8. Although it is less frequently used, annual energy consumption

per student as kWh/student/yr was calculated as well. Table 7 below provides calculated averages for the subcategories.

Table 7: Average energy consumptions and CO2 emissions comparison for all searched categories

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Categories** | **Subcategories** | | | **kWh/student** | **kWh/m2** | **kgCO2/m2** |
| School Type | Primary (42 schools) | | | 766.4 | 71.6 | 12.2 |
| Secondary (13 schools) | | | 519.9 | 62.3 | 18.6 |
| Students’ Shift | Only Morning (25 schools) | | | 1153.9 | 103.1 | 14.9 |
| Morning & Afternoon (30 schools) | | | 336.7 | 41.4 | 12.7 |
| Building Age  – Built Between | 1936-1969 (18 schools) | | | 617.3 | 67.0 | 18.7 |
| 1970-1999 (22 schools) | | | 986.1 | 84.9 | 12.1 |
| 2000-2013 (15 schools) | | | 409.5 | 49.7 | 10.1 |
| The Number of Buildings | 1 (45 schools) | | | 624.7 | 66.5 | 15.5 |
| 2 or more (10 schools) | | | 1083.6 | 82.7 | 5.7 |
| The Number of Floors | 1 (22 schools) | | | 1175.5 | 111.0 | 15.3 |
| 2 (17 schools) | | | 384.2 | 53.0 | 15.5 |
| 3 (16 schools) | | | 409.7 | 29.7 | 9.7 |
| The Number of Students | 1-500 (19 schools) | | | 637.7 | 111.9 | 13.4 |
| 501-1000 (15 schools) | | | 414.5 | 51.9 | 14.4 |
| 1001 or more (21 schools) | | | 313.6 | 43.6 | 13.4 |
| Total School Building Area (m2) | 1-1000 (10 schools) | | | 1256.4 | 173.4 | 24.2 |
| 1001-3000 (8 schools) | | | 1431.9 | 70.5 | 8.5 |
| 3001-5000 (7 schools) | | | 378.4 | 56.8 | 14.2 |
| 5001 or more (30 schools) | | | 409.3 | 37.4 | 11.5 |
| Floor Height (m) | 2.7-3 (12 schools) | | | 1702.3 | 105.5 | 8.6 |
| 3.1 or more (43 schools) | | | 430.7 | 59.3 | 15.1 |
| Extra Building | Yes (33 schools) | | | 391.9 | 46.5 | 12.3 |
| No (22 schools) | | | 1182.5 | 103.9 | 15.7 |
| Energy Type | Electricity + sch.) | wood | (18 | 1348.0 | 93.0 | 6.1 |
| Electricity + Oil (37 sch.) | | | 396.9 | 58.0 | 17.4 |
| Student Density (st/m2) | 0.01-0.2 (43 schools) | | | 799.7 | 53.6 | 10.8 |
| higher than schools) | 0.2 | (12 | 380.1 | 126.2 | 24.0 |
| TOTAL AVERAGE | | | | 708.1 | 69.4 | 13.7 |

**School Type:** Primary schools have got fewer students and cover less area than secondary schools in general. Secondly, it is natural that younger students are more vulnerable to unfavorable conditions. The state primary schools in the Central Municipality consume 14.9% more energy and produce 34.4% less CO2 emission. However, the most significant difference is in annual energy consumption per student and the primary schools consume 47.4% more energy per student than the secondary ones. It is noticeable that the secondary schools produce more CO2 emission although they consume less energy per the unit area. The reason behind that is the energy types used in schools. The secondary schools use more oil than the primary schools do. These types of results also show the importance of energy type preferences.

**Students’ Shift:** The annual energy consumptions per student and meter square between the schools with only morning shift and the schools with morning and afternoon shifts show great difference since energy is consumed for more students and the schools with double shift cover larger areas. The reason behind the greater difference in kWh/st/yr is that the number of students increases although building sizes stay the same in the afternoon shifts. In addition, the schools with the double shift can become warm enough for the last lessons in the afternoon and heaters might be turned off.

**Building Age:** As World Bank (2013) describes the buildings constructed between 1970 and 1999 as buildings with relatively poor construction characteristics, the results in Table 9 above support the claim. It is interesting that school buildings constructed before 1970 consume 21.1% less energy per meter square because the period of the mass construction was experienced in the 1970s and 1980s (World Bank, 2013). In addition, buildings constructed after the year 2000 consume 41.5% less energy per m2 than the ones constructed between 1970 and 1999. The results show that the mass construction did not pay off in the long run to save energy. Additionally, quality of construction seems more significant than the age of the construction.

**Number of Buildings:** The one-building schools spend 19.6% less energy although their CO2 emission average is 2.7 times higher than the multi-building schools and it is a challenging result to analyze. One reason behind that can be that the central heating system Termokos contribution is not billed to the schools in Pristina. On the other side,

the one-building state schools spend 58.3% more energy and produce 52.3% more CO2 emission per m2 than the multi-building schools in the Vushturi Central Municipality. Thus, it is possible that without any specific heating system, the averages of energy consumption and CO2 emission per m2 in one-building schools are more than 50% higher than the multi-building schools.

**Number of School Building Floors:** The number of school building floors show great differences from the point of energy consumption per m2 since the schools with three floors spend 73.2% less energy than the schools with one floor and 44% less energy than the schools with two floors. The differences in CO2 emissions do not seem meaningful. However, in Vushturi, the one-floor schools spend 26.4% more energy than the two-floor and 58.5% more energy than three-floor school buildings per m2 while the one-floor schools produce 36.1% more CO2 emission than two-floor schools and 59.5%

more CO2 emission than three-floor school buildings per m2. The reason behind those

conflicting results can be the central heating system in Pristina

**Number of Students:** The number of students is also related to the size of the school. However, when the number of students is concerned, the average of energy consumption falls down with the increase in the number of students. The schools with around 800 students seem to represent the average of the state school of PCM better. The averages for energy consumption and CO2 emission per meter square for the

schools with less than 200 students were also calculated as 109.6 kWh/m2 and 11.7

kgCO2/m2, respectively. It shows that the state schools with an average number of students between 201 and 1000 are the least energy effective schools in PCM. According to Table 7, the schools with more than 1000 students spend the least energy

per m2. Nevertheless, it should be kept in mind that schools with more students usually

cover wider areas. On the other side, CO2 emission averages do not seem to change in accordance with the number of the students.

**Total School Building Area (m2):** As the size of a school is directly related to the annual energy consumption per meter square, it is most likely that the bigger size a school has, the less energy it spends for each meter square. According to Table 7 above, schools with an area of between 1001 and 3000 m2 represent the average of the state schools in PCM and the most significant drop in energy consumption per meter square appears between the schools with an area of between 1-1000 m2 and 1001-3000 m2.

**Floor Height (m):** The most surprising results seem to appear in the averages according to floor heights. Naturally, schools with higher ceilings should have higher volumes and require more energy at least for heating. Nevertheless, the results for Pristina and Vushturi state schools show the opposite. Thus, there should be other factors eliminating the effects of floor height. Calculations according to school volumes can provide more analyzable results.

**Extra Building:** When the extra buildings are added into calculation, the averages for the schools with extra buildings are 395.9 kWh/st/yr, 41.1 kWh/st/yr and 11.6 kgCO2/m2/yr, respectively. The sizes of the extra buildings in PCM, mostly sports halls, range from 420 to 690 with an average of 601,3 meter square. Even the average is bigger than some schools in the Municipality. Consequently, extra buildings reduce annual energy consumptions and CO2 emissions per meter square considerably. Moreover, heating and lighting hours of extra buildings depend on various factors including school timetables.

**Energy Type:** The right fuel type should be selected for students’ comfort, annual energy consumptions and CO2 emissions. All schools use electricity so that the main difference comes from the other resources. The balance among fuel types plays an important role for annual energy consumptions and CO2 emissions. For instance,

schools with electricity and wood, as an energy resource, spend 60,3% more energy but produce 64.9% less CO2 emission than schools with electricity and oil as energy resource. Thus, fuel type preference in accordance with the related issues such as school structure and fuel cost become crucial. A key concern can be whether school structure should be planned according to the fuel type or vice versa.

**Student Density (student/m2):** According to the research results, there is a sharp difference between the annual energy consumptions and CO2 emissions of the state primary and secondary schools in the PCM based on student density classification. The schools with less than 0.2 st/m2 student density consume much less energy and produce much less CO2 emission per meter square than the schools with more than 0.2 st/m2 student density.

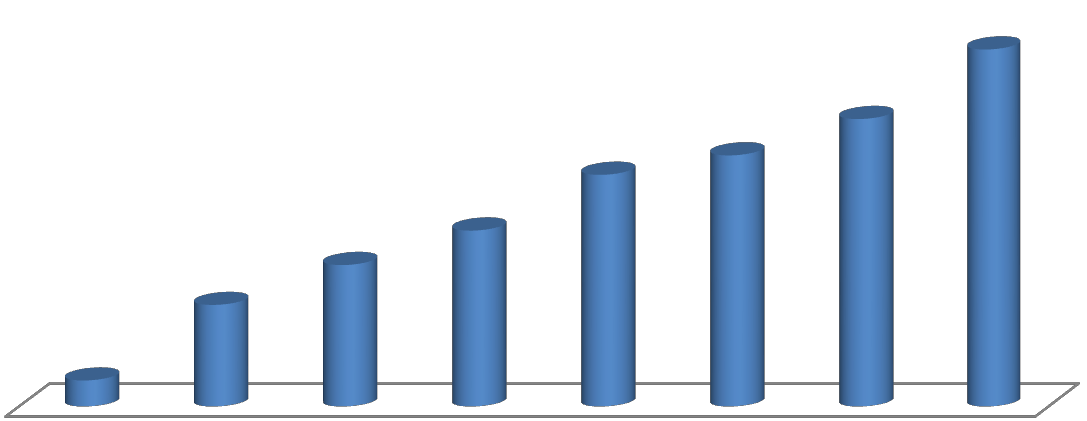
**Extra Building:** When the extra buildings are added to the calculation, the total averages change by 4.6% for annual energy consumption and by 3.8% for the annual CO2 emissions since the averages with extra buildings are 66.2 kWh/m2/yr and 13.2

kgCO2/m2/yr.

Consequently, the school features to reduce energy consumptions according to the research results “for unit area” can be summarized as given below:

* Double-shift (morning and afternoon) schools consume almost 60% less energy than one-shift (only morning) schools.
* One-building schools spend 19.6% less energy than two-building schools.
* Three-floor school buildings spend 73,2% and 44% less energy than one-floor and two-floor school buildings, respectively.
* Schools with a population of more than 1000 students consume 62% and schools with a population of between 501 and 1000 students consume 52.8% less annual energy per meter square than schools with a population of less than 500 students.
* Schools with bigger than 5000 m2 total building area spend 78.5%, 66.2% and 59.3% less energy per m2 than schools smaller than 1000 m2, between 1001 and 3000 m2, and between 3001 and 5000 m2 total building area, respectively.
* Schools with an extra building consume 60.4% less energy per the unit area than schools without an extra building.
* Schools that use electricity and oil as energy sources consume 36.4% less energy per the unit area than school that use electricity and wood. According to the research results in Vushturi, annual school energy consumption averages from the highest to the lowest according to energy source type except for electricity are as wood+coal, wood+coal+oil, wood+oil and only wood.
* Schools with less than 0.2 st/m2 student density consume 57.5% less energy than the schools with more than 0.2 st/m2 student density.

Energy saving school features and how much less energy they spend by percentages compared with the municipality averages are given in Figure 11 below.



57.20%

46.10%

37.20%

40.30%

28.30%

22.80%

16.40%

4.20%

Figure 11: Energy saving school features and their energy saving percentages in comparison with the municipality average

One-building

Only elect. + oil

0-0.2 student

density

Built in 2000 or

later

1000+ students

Double-shift

Bigger than 5000

m2

3-floor building

It is quite interesting that there is only one school that fits the above mentioned low energy consumption features with double-shift, one building, three floors, more than 1000 students (less than 0.2 st/m2 student density), no extra building and larger than 5000 m2, fueled only with electricity and oil. Its annual energy consumptions are as

264.6 kWh/student/yr and 19.3 kWh/m2/yr, and produces 6.8 kgCO2/m2/yr carbon

emission. These averages are 62.6%, 72.2% and 50.4% less than the Municipality averages, respectively. Furthermore, the school consumed the least energy among all the state primary and secondary schools in PCM.

Table 8 below summarizes all the averages for all the subcategories for the state schools in Pristina and Vushturi Central Municipalities to compare both groups of the schools. The most important difference between these two groups of the schools affecting energy consumptions and CO2 emissions is that schools in PCM use only wood or oil in addition to electricity as calculated energy resource while schools in Vushturi Central Municipality use almost all the energy supply variations including coal that increases the averages most. It is worth mentioning that the state schools of PCM are also supported with Termokos Central Heating System that changes energy consumption figures greatly. Furthermore, Termokos provides heating to the state schools in PCM with the help of hot water circulation from a power station and it consequently reduces specifically average CO2 emissions of the schools.

Table 8: Average energy consumptions and CO2 emissions comparison between the state schools in Pristina and Vushturi Central Municipalities for all searched categories

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Categories** | | **Pristina** | | **Vushturi** | |
| **kWh/m2** | **kgCO2/m2** | **kWh/m2** | **kgCO2/m2** |
| School Type | Primary | 71.6 | 12.2 | 180.5 | 49.5 |
| Secondary | 62.3 | 18.6 | 85.1 | 22.5 |
| Students’ Shift | Only Morning | 103.1 | 14.9 | 101.7 | 27.3 |
| Morning & Afternoon | 41.4 | 12.7 | 186.7 | 51.2 |
| Building Age – Built Between | 1936-1969 | 67.0 | 18.7 | 109.9 | 27.9 |
| 1970-1999 | 84.9 | 12.1 | 244.7 | 69.5 |
| 2000-2013 | 49.7 | 10.1 | 163.6 | 44.3 |
| The Number of Buildings | 1 | 66.5 | 15.5 | 203.4 | 55.3 |
| 2 or more | 82.7 | 5.7 | 128.5 | 36.3 |
| The Number of Floors | 1 | 111.0 | 15.3 | 195.1 | 54.4 |
| 2 | 53.0 | 15.5 | 154.3 | 40.0 |
| 3 | 29.7 | 9.7 | 123.1 | 34.1 |
| The Number of Students | 1-500 | 111.9 | 13.4 | 197.8 | 55.4 |
| 501-1000 | 51.9 | 14.4 | 113.5 | 26.8 |
| 1001 or more | 43.6 | 13.4 | 134.2 | 36.0 |
| Total School Building Area (m2) | 0-1000 | 173.4 | 24.2 | 241.6 | 67.3 |
| 1001-3000 | 70.5 | 8.5 | 154.9 | 41.9 |
| 3001-5000 | 56.8 | 14.2 | 95.9 | 25.0 |
| 5001+ | 37.4 | 11.5 | 69.3 | 18.6 |
| Floor Height (m) | 2.7-3 | 105.5 | 8.6 | 201.1 | 57.5 |
| 3.1 or more | 59.3 | 15.1 | 152.8 | 39.7 |
| Extra Building | Yes | 46.5 | 12.3 | 116.7 | 29.9 |
| No | 103.9 | 15.7 | 183.5 | 50.6 |
| Energy Type | Electricity + wood | 93.0 | 6.1 | 40.6 | 3.9 |
| Electricity + Oil | 58.0 | 17.4 |  |  |
| Elec. + wood + Oil |  |  | 65.2 | 9.0 |
| Elec.+wood+Oil+Coal |  |  | 107.6 | 28.2 |
| Elec.+ wood + coal |  |  | 187.6 | 51.9 |
| TOTAL AVERAGE (without including extra buildings) | | 69.4 | 13.7 | 176.7 | 48.4 |
| TOTAL AVERAGE (including extra buildings) | | 66.2 | 13.2 | 176.3 | 48.4 |

Finally, while the state primary and secondary schools in PCM consume 69.4 kWh/m2/yr energy and produce 13.7 kgCO2/m2, the same figures are 176.7 kWh/m2/yr

and 48.4 kgCO2/m2 in Vushturi. These figures by adding extra buildings into calculation are 66.2 kWh/m2/yr and 13.2 kgCO2/m2 for Pristina and 176.3 kWh/m2/yr and 48.4 kgCO2/m2 for Vushturi. For the state schools in PCM, the average differences between the calculations by including extra buildings and without including them are 3.2 kWh/m2/yr for energy consumption and 0.5 kgCO2/m2 CO2 emission. The same differences in Vushturi are 0.4 kWh/m2/yr for energy consumption with no difference in

CO2 emission as there are more state schools with extra buildings in PCM and their average size is 610.3 m2 while the average size of the state schools in Vushturi is 221.2 m2. The average student density in the state schools of PCM is 0.15 st/m2 and 0.213 st/m2 in the state schools in Vushturi Central Municipality.

Despite not being the concern of this dissertation, the averages of six state pre-primary schools were also calculated. There are totally 8 state pre-primary schools in the PCM. Six schools use only electricity and two schools use electricity and oil as energy sources. On average, there are 225 students in 3888 m2 with an 0.15 st/m2 student density. The annual averages of 8 schools are 671.7 kWh per student, 107 kWh per meter square and 15.4 kgCO2/m2 for carbon dioxide emission.

## The Second Stage

The differences between students’ complaint levels in the maximum energy consuming state schools with higher building transparencies and compactness and minimum energy consuming state schools with lower building transparencies and compactness in PCM were investigated in details.

When doing the research in the differences between students’ comfort levels in the highest and the lowest energy consuming state schools per student with high and low building transparencies and compactness, respectively, in PCM, it should be kept in mind that nearly there are not any differences from the point of energy consuming

appliances between state schools in the Municipality as they are poorly equipped. Classrooms have not got any air conditioning systems, computers or projectors. Only few schools started equipping their laboratories with computers and smart boards. Higher-equipped classrooms are usually laboratories such as computer and physics laboratories. Thus, other factors such as the factors in the first stage of the research can play significant roles in school energy consumption and students’ comfort levels. It should also be kept in mind that the research covers only the state primary and secondary schools in PCM for the first stage.

The students’ comfort levels in the highest energy consuming state schools with high building transparencies and compactness and lowest energy consuming state schools with low building transparencies and compactness were compared with the help of Örebro Questionnaire by Örebro University Hospital in Sweden (Anderson, 1993). The complaint level averages for all the items are given in Appendix A. The results were presented in different subcategories. Firstly, the highest and lowest complaints in the schools with the highest and lowest energy consumptions per student were found out. Then the differences between those two categories of schools were compared. Table 9 below shows the highest and lowest levels of students’ complaints in the highest and lowest energy consuming state primary and secondary schools in PCM.

Table 9: The highest and lowest complaint items and their percentages in MAXECSs and MINECSs in PCM

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | In the Highest Energy Consuming Schools | | In the Lowest Energy Consuming Schools | |
| The Highest Levels of Complaints | Do you feel cold in the classroom in WINTER? | 45.4% | Do you feel cold in the classroom in WINTER? | 75% |
| Does the heat/temperature from the Sun disturb? | 44.6% | Does the air feel heavy or poor (bad)? | 65.9% |
| Is there distracting noise or disturbance from the students in the class? | 43.3% | Does the heat/temperature from the Sun disturb? | 65.3% |
| Are you tired? | 41.3% | Is there annoying light from the Sun? | 57.4% |
| Is there annoying light from the Sun? | 40% | Are you tired? | 54.5% |
| Does your head feel heavy? | 37.5% | Are there any unpleasant odors? | 52.3% |
| Is there reflexion from the blackboard? | 37.1% | Is it too hot? / Does the air feel dry? | 45.5% |
| The Lowest Levels of Complaints | Do you have asthma? | 2.9% | Do you have asthma? | 4% |
| Do you use regular medication for asthma or allergies? | 5.8% | Do you use regular medication for asthma or allergies? | 10.2% |
| Do you have a cough? | 7.5% | Do you have a cold? | 11.4% |
| Is there distracting hiss or noise from ventilation or other things in the building? | 7.9% | Is there distracting hiss or noise from ventilation or other things in the building? | 11.9% |
| Do you have a cold? | 10% | Do you have a runny or stuffy nose? | 11.9% |
| Do your hands or face itch? | 10.8% | Do your hands or face itch? | 12.5% |
| Do you have a runny or stuffy nose? | 12.5% | Do you feel the draft on your feet or on your neck? | 13.6% |

Although the complaint levels for none of the items was higher than 50% in the high energy consuming schools, for six items students’ complaint levels were higher than 50% in the low energy consuming schools. The most common complaints in both low and high energy consuming schools are ‘annoying light from the Sun’, ‘disturbing heat from the Sun’, ‘tiredness’ and ‘feeling cold in the classroom in winter’. The first two of them can be related to school or/and classroom design as the light and heat from the sun disturb students in both groups of the schools. Tiredness can be related to numerous factors although heavy sunlight exposure may cause it in hot weathers. However, the most striking result is that the highest level of complaint in average in both groups is that students feel cold in the classroom in winter. Even if 45.4% of the students in high energy consuming schools in PCM feel cold during winter, school energy consumption and students’ comfort practice in state primary and secondary schools in PCM need to be regulated and improved. Furthermore, the same problem in the low energy consuming schools where the complaint percentage was 75% can influence students’ comfort and consequently success levels considerably.

The most common low-level complaints are ‘having asthma’, ‘using regular medication for asthma or allergies’, ‘distracting hiss or noise from ventilation or other things in the building’, ‘having an itchy sense in hands and face’, ‘having a runny or stuffy nose’ and ‘having a cold’. The items related to asthma and itching sense can be explained as Pristina is a small and not heavily industrialized city with relatively less traffic in the city center. It is also understandable that there is little distracting hiss or noise from ventilation or other things as none of the classroom as the author visited and surveyed has got a ventilator, even a computer or projector. In fact, the classrooms have not got any energy consuming appliances except for lighting and heating, and natural ventilation is the only practice for IAQ along with cooling. Additionally, Örebro questionnaire was applied in April and it is natural that students complain little about being cold and having a runny noise. If the same questionnaire was applied in winter, the percentages could be different. Moreover, percentage of feeling cold in classrooms

in winter could be found higher as students may not remember how cold they were in cold seasons and even they would like to feel a bit cooler since chilly weather in the past can seem pleasant in hot seasons.

As the main purpose of the second phase of the research is to find differences in between the students’ comfort levels in high and low energy consuming schools, Table 10 below provides a list of biggest differences in which the complaint percentages are higher in low energy consuming schools.

Table 10: Items with the Highest Comfort Level Differences in Favor of High Energy Consuming Schools and Percentages of the Differences

|  |  |
| --- | --- |
| Items with the Highest Complaint Differences | percentage of difference |
| 18. Do you feel cold in the classroom in WINTER? | 29.6 |
| 21. Does the air feel heavy or poor (bad)? | 26.7 |
| 17. Is there distracting noise outdoors (from the traffic/schoolyard/construction, or the like)? | 20.7 |
| 27. Does the heat/temperature from the Sun disturb? | 20.7 |
| 23. Are there any unpleasant odors (smell)? | 20.6 |
| 22. Does the air feel dry? | 18 |
| 31. Is there annoying light from the Sun? | 17.4 |
| 16. Is it too hot? | 16.7 |

As seen in Table 10 above, the biggest difference occurs in feeling cold in winter although students in both groups of schools expressed the same item as their biggest complaint issue. It shows that even the highest energy consuming schools in PCM have a significant heating problem as 45.4% of students in even highest energy consuming schools suffer from insufficient heating. Items 21 (Does the air feel heavy or poor?), 23 (Are there any unpleasant odors?), 22 (Does the air feel dry?) and 16 (Is it too hot?) also

present the highest differences and they are related to air conditioning in classrooms. These items indicate that students in low energy consuming schools suffer more from indoor air quality and they are more in need of air conditioning systems other than natural ventilation. The other items in the list, items 17 (Is there distracting noise outdoors (from the traffic/schoolyard/construction, or the like)?), 27 (Does the heat/temperature from the Sun disturb?) and 31 (Is there annoying light from the Sun?), are related to schools structure and location, and they can be compensated with the use of electrical appliances since it can be more costly to change the structures and locations of those schools that already exist.

**Number of Lessons:** Average calculations show that complaint levels raise by 6.7% from the first three lessons to the last ones in MAXECSs while the same average fall down by 1.5% in MINECSs. It shows that complaints in MAXECSs are increasing while they are decreasing in MINECSs when the lessons go on. The reason behind these surprising results can be that energy consumption is so insufficient in MINECSs that they notice little difference between the last and the first three lessons or even they may feel better during the last lessons as rooms may get warmer because of breathing. For instance, they complain 27.5% less about having a runny or stuffy nose at the end of the school day. Table 22 below shows the highest students’ complaint differences between the last three and first three lessons in MAXECSs. The negative results in Table 11 and Table 12 show that the complaint levels are higher in the first three lessons.

Table 11: The highest students’ complaint differences between the last and first three lessons in MAXECSs

|  |  |
| --- | --- |
| Items with the Highest Complaint Differences | percentage of difference |
| 5. Does your head feel heavy? | 26.2 |
| 4. Are you tired? | 24.8 |
| 30. Is there reflection from the blackboard? | 20.4 |
| 23. Are there any unpleasant odors? | 18.7 |
| 15. Are you sick or unwell in any other way? | 15.9 |
| 10. Are you hoarse or dry in the throat? | 15.8 |
| 6. Do you have a headache? | 15.0 |
| 8. Do you have trouble concentrating? | 13.4 |
| 31. Is there annoying light from the Sun? | - 12.7 |

The differences in complaints do not seem to be related to the total energy consumption but tiredness and collection of heavy air in the classrooms. However, the raise in most of the above mentioned complaints shown in Table 11 could be compensated with environment comfort appliances, such as air conditioners, and proper lighting and heating/cooling systems. The conditions related to the complaints in items 30, 23 and 10 could be directly improved while the others could be significantly compensated with the help of some appliances. In addition, the students in MAXECSs complain 12.7% less from annoying light from the Sun at the beginning of the school day since they may feel less need of sunlight for lighting and heating. Table 12 below shows the highest complaint percentage differences between the last three and first three lessons in MINECSs.

Table 12: The highest students’ complaint differences between the last and first three lessons in MINECSs

|  |  |
| --- | --- |
| Items with the Highest Complaint Differences | percentage of difference |
| 23. Are there any unpleasant odors? | 36.1 |
| 5. Does your head feel heavy? | 33.6 |
| 11. Do you have a runny or stuffy nose? | - 27.5 |
| 18. Do you feel cold in the classroom in WINTER? | 20.4 |
| 6. Do you have a headache? | 19.7 |

Again, complaints in items 23 and 18 could be directly lessened with proper air conditioning and heating systems while complaints in items 5 and 6 could be reduced by enhanced classroom environment compensated with the help of indoor environment quality appliances and practices. When the first three lessons are concerned, the average of the complaints in the MINECSs is 18.1% higher than that in the MAXECSs and the average complaint level is 10.1% higher in the last three lessons in the MINECSs than that in the last three lessons in the MAXECSs. The difference in the percentages is 8% and it is significant enough showing that complaint level gap between high and low energy consuming schools from the first lessons to the last ones students’ complaint get higher in the high energy consuming schools than low energy consuming schools.

**Window or wall seat:** When the differences are analyzed between the students located near windows and the wall, the averages show that the location from the point of windows and the wall affect students more in the MINECSs than ones in the MAXECSs. While the students near windows in the MAXECSs complain 2.1% more on average, the same difference in the MINECSs is 6.8%. The highest complaint differences between the students near windows and the wall in the maximum and MINECSs are given in Table 13 and Table 14, respectively.

Table 13: The highest students’ complaint differences between the students near windows and the wall in MAXECSs

|  |  |
| --- | --- |
| Items with the Highest Complaint Differences | percentage of difference |
| 30. Is there reflection from the blackboard? | - 18.0 |
| 23. Are there any unpleasant odors? | - 9.9 |
| 5. Does your head feel heavy? | 9.9 |
| 11. Do you have a runny or stuffy nose? | 9.5 |
| 20. Are you plagued (affected negatively) by changing the temperature in the room? | 9.3 |
| 16. Is it too hot? | 8.8 |

The negative percentages in Table 13 indicate higher complaint levels from the wall side than the window side. For instance, students sitting near the wall-sides in the MAXECSs complain about the reflection from the the board 18% more than students sitting near windows. On the other side, students sitting near windows complain more about having a runny or stuffy nose by 9.5%.

Table 14: The highest students’ complaint differences between the students near windows and the wall in MINECSs

|  |  |
| --- | --- |
| Items with the Highest Complaint Differences | percentage of difference |
| 23. Are there any unpleasant odors? | 19.7 |
| 24. Is it hard to hear what is being said in the classroom? | 19.6 |
| 25. Is there distracting noise or disturbance from the students in the class? | 18.1 |
| 8. Do you have trouble concentrating? | 18.1 |
| 16. Is it too hot? | 16.6 |
| 22. Does the air feel dry? | 16.6 |

When students’ locations in the classroom as near windows and the wall are concerned, the average of the complaints from the students near windows in the MINECSs is 11.9% higher than that in the MAXECSs. Furthermore, on average students near the wall in MINECSs complain 7.2% more than the ones in the MAXECSs about their health and well-being. As a common item in Table 13 and Table 14, the students sitting near windows in the MAXECSs complain 8.8% more than the students sitting near the wall about the classroom atmosphere being too hot. The same difference in the percentage is 16.6% in the MINECSs. However, none of the classrooms in both types of the schools have air conditioning and it is difficult to relate the consequence to energy consumption difference. Yet, for those specific schools, it is vivid that students in the MINECSs need more air conditioning.

**Back or front seat:** The average differences in complaint levels between the students sitting at the back and in front of the classrooms in the MAXECSs and MINECSs are almost the same. The percentage difference in the MAXECSs is 4.1%, it is 3.8% in the MINECSs. However, the students sitting at the back of their classrooms in MINECSs complain 9.2% more about their health and well-being conditions in classrooms than the ones with the same location in their classrooms in the MAXECSs. Similarly, the students sitting in front of their classrooms in MINECSs complain 9.4% more about their health and well-being conditions in classrooms that the ones with the same location in their classrooms in the MAXECSs. It means that the percentage differences between the back and front seats are almost the same within both MINECSs and MAXECSs, and in general students sitting at the back of their classrooms complain around 4% more about their health and well-being. Nevertheless, the students’ complaint levels in the MINECSs are between 9.2% and 9.4% higher than the ones’ in the MAXECSs when their locations as the back and front of the classroom are taken into consideration. Moreover, the items with the highest percentage differences that are higher than 10% between the back and front seat students in the MAXECSs and

MINECSs are totally different. Table 15 and Table 16 below show the items with the highest complaint differences in both types of the schools.

Table 15: The highest students’ complaint differences between the students sitting at the back and in the front of classrooms in MAXECSs

|  |  |
| --- | --- |
| Items with the Highest Complaint Differences | percentage of difference |
| 4. Are you tired? | 21.4 |
| 6. Do you have a headache? | 13.1 |
| 17. Does the heat/temperature from the Sun disturb? | 12.7 |
| 18. Do you feel cold in the classroom in WINTER? | 11.5 |
| 19. Do you feel the draft on your feet or on your neck? | 10.4 |
| 9. Do your eyes itch or sting? | 10.3 |

According to Table 15, the students sitting at the back of their classrooms in the MAXECSs 24% feel by more tired than the ones in the same location in their classrooms in the MINECSs.

Table 16: The highest students’ complaint differences between the students sitting at the back and in the front of classrooms in MINECSs

|  |  |
| --- | --- |
| Items with the Highest Complaint Differences | percentage of difference |
| 8. Do you have trouble concentrating? | 16.4 |
| 28. Is there distracting hiss or noise from ventilation or other things in the building? | 14.8 |
| 22. Does the air feel dry? | 14.6 |
| 5. Does your head feel heavy? | 11.7 |
| 24. Is it hard to hear what is being said in the classroom? | 10.2 |

If it is necessary to compare students’ complaint levels in the MAXESCs and MINECSs for the three categories as the last-first three lessons, window-wall seats and back-front seats, it can be summarized that in all categories the students in the MINECSs complain more about their health and well-being in their classrooms. Table 17 below summarizes the differences as percentages.

Table 17: Students’ complaint level differences as percentage between the schools with MAXECSs and MINECSs

|  |  |
| --- | --- |
| Comparison Categories (MINECSs – MAXECSs) | percentage of difference |
| The last three lessons | 10.1 |
| The first three lessons | 18.1 |
| Window seats | 11.9 |
| Wall seats | 7.2 |
| Back seats | 9.2 |
| Front seats | 9.4 |

The items with the higher than 20% complaint differences between the MAXECSs and MINECSs from the points of the last three lessons, the first three lessons, window seats, wall seats, back seats and front seats are given Tables 20, 21, 22, 23, 24 and 25, respectively. Positive percentages of differences show higher complaint levels in the MINECSs.

Table 18: Items with the highest students’ complaint level differences and their percentages of differences for the last three lessons between MAXECSs and MINECSs

|  |  |
| --- | --- |
| Items with the Higher than 20% Differences (MINECSs – MAXECSs) | percentage of difference |
| 18. Do you feel cold in the classroom in WINTER? | 42.2 |
| 21. Does the air feel heavy or poor? | 32.5 |
| 17. Does the heat/temperature from the Sun disturb? | 23.9 |
| 27. Is there distracting noise outdoors (from the traffic/schoolyard/construction, or the like)? | 25.0 |
| 31. Is there annoying light from the Sun? | 23.4 |

Students’ comfort in schools does not depend on only energy consumption as there are several other factors affecting it. However, as seen from the Table 18 above two of the highest differences for the last three lessons are strongly related to energy consumption in schools.

Table 19: Items with the highest students’ complaint level differences for the first three lessons between MAXECSs and MINECSs

|  |  |
| --- | --- |
| Items with the Higher than 20% Differences | percentage of difference |
| 27. Is there distracting noise outdoors (from the traffic/schoolyard/construction, or the like)? | 47.2 |
| 21. Does the air feel heavy or poor? | 38.1 |
| 26. Is there disturbing noise from the students or teachers of other classes or classrooms? | 36.5 |
| 4. Are you tired? | 36.4 |
| 22. Does the air feel dry? | 32.8 |
| 17. Does the heat/temperature from the Sun disturb? | 30.9 |
| 18. Do you feel cold in the classroom in WINTER? | 30.9 |

Three of the highest differences between the MAXECSs and MINECSs for the first three lessons as poor or heavy air, and dry indoor air, and feeling cold in winter can be compensated by using proper air ventilation systems along with well-functioning heating system.

Table 20: Items with the highest students’ complaint level differences for the window seats between MAXECSs and MINECSs

|  |  |
| --- | --- |
| Items with the Higher than 20% Differences | percentage of difference |
| 23. Are there any unpleasant odors? | 36.5 |
| 18. Do you feel cold in the classroom in WINTER? | 28.1 |
| 22. Does the air feel dry? | 27.1 |
| 21. Does the air feel heavy or poor? | 26.9 |
| 31. Is there annoying light from the Sun? | 24.9 |
| 8. Do you have trouble concentrating? | 23.0 |
| 16. Is it too hot? | 20.6 |

For the concerns of the students who sit near windows in the MINECSs, properly installed appliances can directly reduce the gap for all the items except for concentration trouble. Although the lack of concentration can occur for various reasons, in some cases with the collection of several ones, a quality indoor atmosphere will surely help students to improve their concentrations. Furthermore, disturbance from the sunlight can be reduced with a proper and healthy indoor lighting although it brings more expenses.

Table 21: Items with the highest students’ complaint level differences for the wall seats between MAXECSs and MINECSs

|  |  |
| --- | --- |
| Items with the Higher than 20% Differences | percentage of difference |
| 18. Do you feel cold in the classroom in WINTER? | 31.1 |
| 27. Is there distracting noise outdoors (from the traffic/schoolyard/construction, or the like)? | 27.4 |
| 21. Does the air feel heavy or poor? | 26.3 |
| 17. Does the heat/temperature from the Sun disturb? | 22.0 |

The two common items between the students sitting near windows and the wall are Item 18 (Do you feel cold in the classroom in WINTER?) and Item 21 (Does the air feel heavy or poor?). It is worth mentioning that their percentages are almost the same.

Table 22: Items with the highest students’ complaint level differences for the back seats between MAXECSs and MINECSs

|  |  |
| --- | --- |
| Items with the Higher than 20% Differences | percentage of difference |
| 21. Does the air feel heavy or poor? | 29.6 |
| 27. Is there distracting noise outdoors (from the traffic/schoolyard/construction, or the like)? | 28.4 |
| 22. Does the air feel dry? | 27.4 |
| 17. Does the heat/temperature from the Sun disturb? | 24.3 |
| 18. Do you feel cold in the classroom in WINTER? | 20.6 |
| 16. Is it too hot? | 20.4 |
| 8. Do you have trouble concentrating? | 20.4 |
| 16. Is it too hot? | 20.4 |

As again, feeling cold in winter, heat from the Sun and poor indoor air can be enhanced with better indoor heating and an air conditioner.

Table 23: Items with the highest students’ complaint level differences for the front seats between MAXECSs and MINECSs

|  |  |
| --- | --- |
| Items with the Higher than 20% Differences | percentage of difference |
| 18. Do you feel cold in the classroom in WINTER? | 33.4 |
| 21. Does the air feel heavy or poor? | 25.4 |
| 23. Are there any unpleasant odors? | 22.3 |

All the complaints in Table 23 above are energy consumption related items unless natural solutions are not available, and they can be reduced with the help of proper heating and air conditioning systems that require more energy consumption in schools. Furthermore, like the comparison between the students sitting near windows and the wall, the two common items between back and front seaters are Items 18 and 21. In fact, Items 18 relating to being cold in winter and Item 21 relating to poor indoor air are common in all subdivisions. It means that in general feeling cold in winter and poor indoor air are problematic issues for all the students in all subdivisions in both the maximum and minimum energy consuming state schools in PCM. Thus, they should be handled as the first concerns for students’ health, well-being and quality school indoor environment.

Finally, subcategories such as the complaint percentages of the students having the last three lessons, sitting near windows and at the back of the classrooms in MAXECSs and MINECSs are given below in Table 24 to compare their complaint levels as percentages.

Table 24: Comparison of students’ complaint percentages for subcategories in MAXECSs and MINECSs

|  |  |  |  |
| --- | --- | --- | --- |
| Students With | Complaint Percentages | | percentage of difference |
| In  MAXECSs | In  MINECSs |
| Last three lessons – Window & Back Seat | 33.4 | 45.1 | 11.7 |
| Last three lessons – Window & Front Seat | 25.5 | 40.9 | 15.4 |
| Last three lessons – Wall & Back Seat | 29.2 | 35.1 | 5.9 |
| Last three lessons – Wall & Front Seat | 24.5 | 32.3 | 7.8 |
| First three lessons – Window & Back Seat | 16.0 | 39.6 | 23.6 |
| First three lessons – Window & Front Seat | 23.8 | 29.9 | 6.1 |
| First three lessons – Wall & Back Seat | 26.5 | 25.8 | - 0.7 |
| First three lessons – Wall & Front Seat | 16.4 | 28.7 | 12.3 |

As seen from Table 24 above, for all the categories, except for students having their first three lessons, sitting near the wall at the back of their classrooms with less than 1% difference, students’ complaint percentages in the MINECSs are higher than the ones in the MAXECSs. Also, the students with the highest complaint percentages are the ones who were having their last three lessons, sitting near windows at the back of their classrooms in both the MAXECSs and MINECSs. Students having the last three lessons, sitting near windows at the back of their classrooms in the MINECSs also have the highest complaint percentage followed by the students who were having their last three lessons sitting near windows at the back of their classrooms among all the categories. The students with the lowest complaint percentage in the MINECSs were the ones having their first three lessons sitting near the wall at the back of their classrooms. Again, the students with the lowest complaint percentage in the MAXECSs were the ones having their first three lessons sitting near the wall in the front of their classrooms. The subcategory with the biggest difference between the MINECSs and

MAXECSs was the category with students having their first three lessons sitting near windows at the back of their classrooms with 23.6% difference. The lowest difference between the two types of schools occurs among the students having their first three lessons sitting near the wall at the back of their classrooms with 0.7% difference. Furthermore, when the highest complaint levels in MAXECSs and MINECSs are taken into consideration, it can be derived from the percentages in Table 36 that students at the back of their classrooms in MAXECSs and students near windows in MINECSs have the highest complaint levels.

According to the categories, the highest correlations based on students’ complaint levels appear between the students sitting near the wall in low energy consuming school and the students sitting near windows in high energy consuming schools (0.9), and between the students sitting in front of their classrooms in low energy consuming schools and the students sitting at the back their classrooms in high energy consuming schools (0.89).

All in all, according to the students’ responses to Örebro survey, the average complaint percentage in the maximum energy consuming state schools in PCM was found 23.9% whereas the same figure for the minimum energy consuming state schools in PCM was calculated as 33.3%. The difference was 9.4%. That means the students in the minimum energy consuming state schools in PCM state that they feel 9.4% less comfortable about their health and well-being in their schools in comparison with the maximum energy consuming state schools in the same municipality.

The results of the students’ comfort level survey can be summarized as:

* The highest complaint level differences, all higher than 20%, between high and low energy consuming schools occur on complaints about feeling cold in the classroom in winter (29.6%), poor or heavy air (26.7), distracting outdoor noise and disturbing heat from the Sun (20.7%) and unpleasant odor (20.6%).
* The highest complaint level differences for the main categories between the high and low energy consuming school occur at the first three (18.1%) and last three lessons (10.1), and between the students sitting near windows (11.9%).
* The highest complaint level differences for the subcategories between the students of high and low energy consuming school occur at the first three lessons at back window seats (23.6%), at the last three lessons at front window seats (15.4%) and at the first three lessons at front wall seats (12.3%),
* The lowest complaint level differences for the subcategories between the students of the high and low energy consuming school occur at the first three lessons at the back seats near the wall (0.7%), at the last three lessons at the back seats near the wall (5.9%) and at the first three lessons at front window seats (6.1%).

## Analyses of the Research Hypotheses

**H1:** Study shift as morning and morning + afternoon, number of school building floors and 0.2 st/m2 student density, are statistically significant predictors of annual school energy consumption per student (kWh/st/yr) and unit area (kWh/m2/yr), annual CO2 emission per unit area (kg CO2/m2/yr).

Tae-Woo et al. (2012) state that the school schedule affects elementary schools’ energy consumption. Moreover, daily period of schools affects school building heating consumption (Pereira et al., 2014). It is expected that schools with double shifts spend less energy per meter square than schools with only one shift because schools with double shift make use of energy used in the morning shift. Furthermore, it is assumed that multi-floor buildings can consume less energy per meter square due to heating exchange between building floors. Office of Energy Efficiency of Canada (2012) in its report titled Survey of Commercial and Institutional Energy Use – Buildings 2009

Detailed Statistical Report December, 2012 states that two and three-floor buildings have better energy intensity than one-floor buildings. Finally, average annual energy consumptions of big-size school buildings can be low due to the nature of the calculation. However, it is debatable issue that school buildings should be as big as possible. Secondly, students’ physical and environmental comfort plays an important role on their health, well-being and consequently outcome. Thus, to merge the aspects of energy consumption as school area and the number of students in a school, student density can be used as a reference. Hong et al.’s analyses (2012) show 0.575 of correlation between number of students per unit class and electric energy consumption while -0.027 of correlation between number of students per unit class and electric energy consumption per meter square.

The null hypothesis:

H0:  energy consumptions per unit area of one-floor school buildings, with more than

0.2 student density and only morning shift =  energy consumptions per unit area of multi-floor (2 or 3) school buildings with less than 0.2 student density and only morning

+ afternoon shifts

The alternate hypothesis:

HA:  energy consumptions per unit area of one-floor school buildings, with more than

0.2 student density and only morning shift ≠  energy consumptions per unit area of multi-floor (2 or 3) school buildings with less than 0.2 student density and only morning

+ afternoon shifts

The Multivariate Tests table in Table 25 below shows that annual school energy consumption per student (kWh/st/yr), annual school energy consumption per unit area (kWh/m2/yr) and annual CO2 emission per unit area (kg CO2/m2/yr) are significantly dependent on which prior;

1. student density,
2. study shift

(*p* < .0005) by the MANOVA whereas number of school building floors is not.

Likewise, they are statistically significantly dependent on which prior;

a) student density combined with study shift

while not on which prior student density combined with number of school building floors, number of school building floors combined with study shift, and student density combined with number of school building floors and study shift.

Table 25: Multivariate Testsa for Hypothesis 1

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Effect | | Value | F | Hypothesis df | Error df | Sig. | Partial Eta Squared |
| Intercept | Pillai's Trace | .834 | 71.910b | 3.000 | 43.000 | .000 | .834 |
| Wilks' Lambda | .166 | 71.910b | 3.000 | 43.000 | .000 | .834 |
| Hotelling's Trace | 5.017 | 71.910b | 3.000 | 43.000 | .000 | .834 |
| Roy's Largest Root | 5.017 | 71.910b | 3.000 | 43.000 | .000 | .834 |
| Student Density | Pillai's Trace | .488 | 13.689b | 3.000 | 43.000 | .000 | .488 |
| Wilks' Lambda | .512 | 13.689b | 3.000 | 43.000 | .000 | .488 |
| Hotelling's Trace | .955 | 13.689b | 3.000 | 43.000 | .000 | .488 |
| Roy's Largest Root | .955 | 13.689b | 3.000 | 43.000 | .000 | .488 |
| Number of School Building Floors | Pillai's Trace | .177 | 1.428 | 6.000 | 88.000 | .213 | .089 |
| Wilks' Lambda | .823 | 1.467b | 6.000 | 86.000 | .199 | .093 |
| Hotelling's Trace | .215 | 1.502 | 6.000 | 84.000 | .187 | .097 |
| Roy's Largest Root | .212 | 3.115c | 3.000 | 44.000 | .036 | .175 |
| Study Shift | Pillai's Trace | .374 | 8.573b | 3.000 | 43.000 | .000 | .374 |
| Wilks' Lambda | .626 | 8.573b | 3.000 | 43.000 | .000 | .374 |
| Hotelling's Trace | .598 | 8.573b | 3.000 | 43.000 | .000 | .374 |
| Roy's Largest Root | .598 | 8.573b | 3.000 | 43.000 | .000 | .374 |
| Student Density  \* Number of School Building  Floors | Pillai's Trace | .011 | .159b | 3.000 | 43.000 | .924 | .011 |
| Wilks' Lambda | .989 | .159b | 3.000 | 43.000 | .924 | .011 |
| Hotelling's Trace | .011 | .159b | 3.000 | 43.000 | .924 | .011 |
| Roy's Largest Root | .011 | .159b | 3.000 | 43.000 | .924 | .011 |

Table 25: Multivariate Testsa for Hypothesis 1 (continued)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Student Density  \* Study Shift | Pillai's Trace | .292 | 5.901b | 3.000 | 43.000 | .002 | .292 |
| Wilks' Lambda | .708 | 5.901b | 3.000 | 43.000 | .002 | .292 |
| Hotelling's Trace | .412 | 5.901b | 3.000 | 43.000 | .002 | .292 |
| Roy's Largest Root | .412 | 5.901b | 3.000 | 43.000 | .002 | .292 |
| Number of School Building Floors \* Study  Shift | Pillai's Trace | .147 | 1.159 | 6.000 | 88.000 | .335 | .073 |
| Wilks' Lambda | .854 | 1.173b | 6.000 | 86.000 | .328 | .076 |
| Hotelling's Trace | .169 | 1.184 | 6.000 | 84.000 | .323 | .078 |
| Roy's Largest Root | .162 | 2.379c | 3.000 | 44.000 | .083 | .140 |
| Student Density  \* Number of School Building Floors \* Study  Shift | Pillai's Trace | .012 | .172b | 3.000 | 43.000 | .915 | .012 |
| Wilks' Lambda | .988 | .172b | 3.000 | 43.000 | .915 | .012 |
| Hotelling's Trace | .012 | .172b | 3.000 | 43.000 | .915 | .012 |
| Roy's Largest Root | .012 | .172b | 3.000 | 43.000 | .915 | .012 |

1. Design: Intercept + Student Density + Number of School Building Floors + Study Shift + Student Density \* Number of School Building Floors + Student Density \* Study Shift + Number of School Building Floors \* Study Shift + Student Density \* Number of School Building Floors \* Study Shift
2. Exact statistic
3. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 26 below shows Tests of Between-Subjects Effects for Hypothesis 1. Table 26: Tests of Between-Subjects Effects for Hypothesis 1

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
| Corrected Model | Annual Energy Consumption per Unit Area | 157354.858a | 9 | 17483.873 | 24.658 | .000 | .831 |
| Annual CO2 Emission per Unit Area | 4861.297b | 9 | 540.144 | 4.796 | .000 | .490 |
| Annual Energy Consumption per Student | 15027310.0  84c | 9 | 1669701.120 | 3.936 | .001 | .440 |

Table 26: Tests of Between-Subjects Effects for Hypothesis 1 (continued)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Intercept | Annual Energy Consumption per Unit Area | 153856.238 | 1 | 153856.238 | 216.98  9 | .000 | .828 |
| Annual CO2 Emission per Unit Area | 8983.641 | 1 | 8983.641 | 79.763 | .000 | .639 |
| Annual Energy Consumption per Student | 6641818.43  5 | 1 | 6641818.435 | 15.658 | .000 | .258 |
| Student Density | Annual Energy Consumption per Unit Area | 26081.444 | 1 | 26081.444 | 36.784 | .000 | .450 |
| Annual CO2 Emission per Unit Area | 1717.180 | 1 | 1717.180 | 15.246 | .000 | .253 |
| Annual Energy Consumption per Student | 592175.561 | 1 | 592175.561 | 1.396 | .244 | .030 |
| + Number of School Building Floors | Annual Energy Consumption per Unit Area | 4325.641 | 2 | 2162.821 | 3.050 | .057 | .119 |
| Annual CO2 Emission per Unit Area | 23.227 | 2 | 11.613 | .103 | .902 | .005 |
| Annual Energy Consumption per Student | 537540.031 | 2 | 268770.015 | .634 | .535 | .027 |
| Study Shift | Annual Energy Consumption per Unit Area | 18037.709 | 1 | 18037.709 | 25.439 | .000 | .361 |
| Annual CO2 Emission per Unit Area | 295.265 | 1 | 295.265 | 2.622 | .112 | .055 |
| Annual Energy Consumption per Student | 1195519.84  7 | 1 | 1195519.847 | 2.818 | .100 | .059 |
| Student Density \* + Number of School Building  Floors | Annual Energy Consumption per Unit Area | 51.777 | 1 | 51.777 | .073 | .788 | .002 |
| Annual CO2 Emission per Unit Area | 8.667 | 1 | 8.667 | .077 | .783 | .002 |
| Annual Energy Consumption per Student | 77209.620 | 1 | 77209.620 | .182 | .672 | .004 |
| Student Density \* Study Shift | Annual Energy Consumption per Unit Area | 11140.645 | 1 | 11140.645 | 15.712 | .000 | .259 |
| Annual CO2 Emission per Unit Area | 647.300 | 1 | 647.300 | 5.747 | .021 | .113 |
| Annual Energy Consumption per Student | 355935.285 | 1 | 355935.285 | .839 | .365 | .018 |

Table 26: Tests of Between-Subjects Effects for Hypothesis 1 (continued)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| + Number of School Building Floors \* Study Shift | Annual Energy Consumption per Unit Area | 1745.472 | 2 | 872.736 | 1.231 | .302 | .052 |
| Annual CO2 Emission per Unit Area | 157.166 | 2 | 78.583 | .698 | .503 | .030 |
| Annual Energy Consumption per Student | 652436.042 | 2 | 326218.021 | .769 | .469 | .033 |
| Student Density \* + Number of School Building Floors \*  Study Shift | Annual Energy Consumption per Unit Area | 34.437 | 1 | 34.437 | .049 | .827 | .001 |
| Annual CO2 Emission per Unit Area | 6.695 | 1 | 6.695 | .059 | .808 | .001 |
| Annual Energy Consumption per Student | 126031.842 | 1 | 126031.842 | .297 | .588 | .007 |
| Error | Annual Energy Consumption per Unit Area | 31907.338 | 45 | 709.052 |  |  |  |
| Annual CO2 Emission per Unit Area | 5068.311 | 45 | 112.629 |  |  |  |
| Annual Energy Consumption per Student | 19088392.3  88 | 45 | 424186.498 |  |  |  |
| Total | Annual Energy Consumption per Unit Area | 454495.220 | 55 |  |  |  |  |
| Annual CO2 Emission per Unit Area | 20260.780 | 55 |  |  |  |  |
| Annual Energy Consumption per Student | 61696126.7  50 | 55 |  |  |  |  |
| Corrected Total | Annual Energy Consumption per Unit Area | 189262.195 | 54 |  |  |  |  |
| Annual CO2 Emission per Unit Area | 9929.608 | 54 |  |  |  |  |
| Annual Energy Consumption per Student | 34115702.4  72 | 54 |  |  |  |  |

1. R Squared = .831 (Adjusted R Squared = .798)
2. R Squared = .490 (Adjusted R Squared = .387)
3. R Squared = .440 (Adjusted R Squared = .329)

According to Table 26 above, student density has a statistically significant effect on both;

1. Annual energy consumption per unit area (*F* (1, 57) = 36.784; *p* < .0005; partial η2 =

.45)

1. Annual CO2 emission per unit area (*F* (1, 57) = 15.246; *p* < .0005; partial η2 = .25)

Study Shift density has a statistically significant effect on;

a) Annual energy consumption per unit area (*F* (1, 57) = 25.439; *p* < .0005; partial η2 = .361)

Student Density combined with Study Shift has a statistically significant effect on both;

1. Annual energy consumption per unit area (*F* (1, 57) = 15.712; *p* < .0005; partial η2 = .259)
2. Annual CO2 emission per unit area (*F* (1, 57) = 5.747; *p* < .0005; partial η2 = .113) Table 27 below shows Multiple Comparisons (LSD) for Hypothesis 1.

Table 27: Multiple Comparisons (LSD) for Hypothesis 1

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Dependent Variable | (I) floor number | (J) floor number | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
| Lower Bound | Upper Bound |
| Annual Energy Consumption per Unit Area | 1.00 | 2.00 | 58.0128\* | 8.59875 | .000 | 40.6941 | 75.3316 |
| 3.00 | 81.3364\* | 8.74902 | .000 | 63.7149 | 98.9578 |
| 2.00 | 1.00 | -58.0128\* | 8.59875 | .000 | -75.3316 | -40.6941 |
| 3.00 | 23.3235\* | 9.27495 | .016 | 4.6428 | 42.0042 |
| 3.00 | 1.00 | -81.3364\* | 8.74902 | .000 | -98.9578 | -63.7149 |
| 2.00 | -23.3235\* | 9.27495 | .016 | -42.0042 | -4.6428 |
| Annual CO2 Emission per Unit Area | 1.00 | 2.00 | -.2051 | 3.42706 | .953 | -7.1075 | 6.6974 |
| 3.00 | 5.6210 | 3.48695 | .114 | -1.4021 | 12.6441 |
| 2.00 | 1.00 | .2051 | 3.42706 | .953 | -6.6974 | 7.1075 |
| 3.00 | 5.8261 | 3.69656 | .122 | -1.6192 | 13.2714 |
| 3.00 | 1.00 | -5.6210 | 3.48695 | .114 | -12.6441 | 1.4021 |
| 2.00 | -5.8261 | 3.69656 | .122 | -13.2714 | 1.6192 |
| Annual Energy Consumption per Student | 1.00 | 2.00 | 791.2864\* | 210.31726 | .000 | 367.6857 | 1214.8871 |
| 3.00 | 765.7614\* | 213.99266 | .001 | 334.7580 | 1196.7647 |
| 2.00 | 1.00 | -791.2864\* | 210.31726 | .000 | -1214.8871 | -367.6857 |
| 3.00 | -25.5250 | 226.85635 | .911 | -482.4371 | 431.3871 |
| 3.00 | 1.00 | -765.7614\* | 213.99266 | .001 | -1196.7647 | -334.7580 |
| 2.00 | 25.5250 | 226.85635 | .911 | -431.3871 | 482.4371 |

Based on observed means.

The error term is Mean Square(Error) = 424186.498.

\*. The mean difference is significant at the .05 level.

Table 27 above shows that for mean scores for annual energy consumption per unit area were statistically significantly different among all the 1, 2 and 3 building floors (*p* <

.0005). Likewise, mean scores for annual energy consumption per student statistically significantly different between 1 and 2 building floors (*p* < .0005), but not between 2 and 3 building floors (*p* = .911). Mean Annual CO2 emission per unit area scores were not statistically significantly different among any numbers of building floors.

**H2:** Annual school energy consumption per meter square (kWh/m2/yr) can be statistically significant predictor for annual school energy consumption per student (kWh/st/yr) and annual CO2 emission per unit area (kg CO2/m2/yr).

Annual school energy consumption per student and meter square are two different building energy consumption parameters as the second one is the most common one by far in literature and practice.

Correlation coefficient test was used to see whether there is a correlation between the groups of figures. Based on the above-given calculation methods, the results do not show a significant correlation between energy consumption per student (M= 708.1) and per m2 (M= 69.4) with a correlation co-efficiency of 0.1767. Although technically a

positive correlation, the relationship between variables is weak. Thus, annual school energy consumption per student and meter square cannot be statistically significant predictors for each other. Table 28 and Figure 12 below show Pearson Correlation Coefficient results and related graphic, respectively.

Table 28: Pearson Correlation Coefficient results for annual school energy consumption per student and meter square

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | ∑ | Mean | SS | N | R | R2 |
| X=Annual Energy Consumption per Student | 38947.7 | 708.14 | 34115702.47 | 55 | 0.1767 | 0.0312 |
| Y=Annual Energy Consumption per Unit Area | 3819.4 | 69.444 | 189262.195 |
| X and Y Combined | 448996 |  |  |

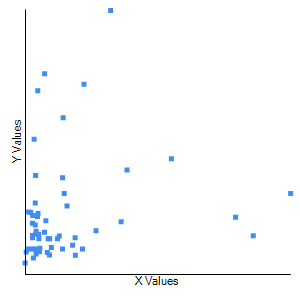


Figure 12: Pearson Correlation Coefficient graphic for annual school energy consumption per student and meter square in the state primary and secondary schools in PCM (X=Annual Energy Consumption per Student and Y=Annual Energy Consumption per Unit Area).

Additionally, Spearman’s Rho, a non-parametric test used to ration the strength of correlation between two variables, was applied to variables.

According to the above-given calculation method, the R value of Spearman’s Rho for hypothesis 8 is 0.25162 with the *p*-value of 0.06386. The results show that the correlation between annual school energy consumption per student and meter square are not statistically significant. Table 29 below shows Spearman’s Rho Correlation results.

Table 29: Spearman’s Rho Correlation results for annual school energy consumption per student and meter square

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Mean | Standard Deviation | Combined Covariance | R | P |
| Spearman’s Rho Correlation | 28 | 16.02 | 64.56 | 0.25162 | 0.06386 |

As a result, both Pearson Correlation Coefficient and Spearman’s Rho Correlation calculation results show that there is no statistically significant correlation between annual school energy consumption per student and meter square.

Furthermore, annual school energy consumption and CO2 emission per meter square are two different building energy consumption parameters as the first one is mostly concerned about energy efficiency while the second one is mostly about environmental concerns. Buildings in European Union are responsible for the 40% of total energy consumption and 36% of CO2 emissions (Thewes et. al, 2014). Consequently, it might be possible to assume from these close percentages that there is a significant correlation between annual school energy consumption and CO2 emission levels per meter.

Correlation coefficient test was used to see whether there is a correlation between the groups of figures. The results show a moderate positive correlation between annual energy consumption per meter square (M= 69.4) and CO2 emission per meter square (M= 13.7) with a correlation co-efficiency of 0.6383, which means there is a tendency for high annual energy consumption per meter square variable scores go with high annual CO2 emission per meter square variable scores (and vice versa). Thus, annual school energy consumption and CO2 emission per meter square are statistically moderate predictors for each other. Thus, fuel types should be taken into consideration as well. Table 30 and Figure 13 below show Pearson Correlation Coefficient results and the related graphic, respectively.

Table 30: Pearson Correlation Coefficient results for annual school energy consumption meter square and CO2 emission meter square

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | ∑ | Mean | SS | N | R | R2 |
| X=Annual Energy Consumption per Unit Area | 3819.4 | 69.444 | 189262.195 | 55 | 0.6383 | 0.4074 |
| Y=Annual CO2 emission per Unit Area | 753.8 | 13.705 | 9929.608 |
| X and Y Combined | 27670.857 |  |  |

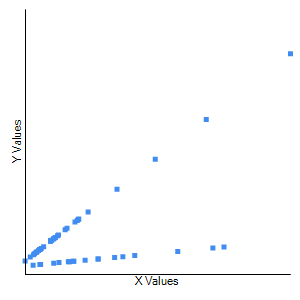


Figure 13: Pearson Correlation Coefficient graphic for annual school energy consumption meter square and CO2 emission per meter square in the state primary and secondary schools in PCM (X=Annual Energy Consumption per meter square and Y=Annual Energy Consumption per CO2 emission per meter square).

Also, Spearman’s Rho was applied to variables. The R value of Spearman’s Rho was calculated as 0.331 with the *p*-value of 0.01368. The results show that the correlation between annual school energy consumption per student and meter square are not statistically significant. Table 31 below shows Spearman’s Rho Correlation results.

Table 31: Spearman’s Rho Correlation results for annual school energy consumption per student and meter square

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Mean | Standard Deviation | Combined Covariance | R | P |
| Spearman’s Rho Correlation | 28 | 16.01 | 84.81 | 0.331 | 0.01368 |

As a result, both Pearson Correlation Coefficient and Spearman’s Rho Correlation calculation results show that there is no statistically significant correlation between annual school energy consumption per student and meter square.

Additionally, Manova test results given in Table 32 and Table 33 below also show that there is no statistically significant correlation among annual school energy consumption per student (kWh/st/yr), annual school energy consumption meter square (kWh/m2/yr) and annual CO2 emission per unit area (kg CO2/m2/yr).

Table 32: Multivariate Testsa for the Hypothesis 2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Effect | | Value | F | Hypothesis df | Error df | Sig. | Partial Eta Squared |
| Intercept | Pillai's Trace | .822 | 27.757b | 1.000 | 6.000 | .002 | .822 |
| Wilks' Lambda | .178 | 27.757b | 1.000 | 6.000 | .002 | .822 |
| Hotelling's Trace | 4.626 | 27.757b | 1.000 | 6.000 | .002 | .822 |
| Roy's Largest Root | 4.626 | 27.757b | 1.000 | 6.000 | .002 | .822 |
| Annual Energy Consumption per Unit Area | Pillai's Trace | .841 | .659b | 48.000 | 6.000 | .807 | .841 |
| Wilks' Lambda | .159 | .659b | 48.000 | 6.000 | .807 | .841 |
| Hotelling's Trace | 5.271 | .659b | 48.000 | 6.000 | .807 | .841 |
| Roy's Largest Root | 5.271 | .659b | 48.000 | 6.000 | .807 | .841 |

1. Design: Intercept + Annual Energy Consumption per Unit Area
2. Exact statistic

Table 33: Tests of Between-Subjects Effects for the Hypothesis 2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta  Squared |
| Corrected Model | Annual Energy Consumption per Student | 28675347.177a | 48 | 597403.066 | .659 | .807 | .841 |
| Annual CO2 Emission per Unit Area | 9929.608b | 48 | 206.867 | . | . | 1.000 |
| Intercept | Annual Energy Consumption per Student | 25167660.579 | 1 | 25167660.579 | 27.757 | .002 | .822 |
| Annual CO2 Emission per Unit Area | 10114.790 | 1 | 10114.790 | . | . | 1.000 |
| Annual Energy Consumption per Unit Area | Annual Energy Consumption per Student | 28675347.177 | 48 | 597403.066 | .659 | .807 | .841 |
| Annual CO2 Emission per Unit Area | 9929.608 | 48 | 206.867 | . | . | 1.000 |
| Error | Annual Energy Consumption per Student | 5440355.295 | 6 | 906725.883 |  |  |  |
| Annual CO2 Emission per Unit Area | .000 | 6 | .000 |  |  |  |
| Total | Annual Energy Consumption per Student | 61696126.750 | 55 |  |  |  |  |
| Annual CO2 Emission per Unit Area | 20260.780 | 55 |  |  |  |  |
| Corrected Total | Annual Energy Consumption per Student | 34115702.472 | 54 |  |  |  |  |
| Annual CO2 Emission per Unit Area | 9929.608 | 54 |  |  |  |  |

1. R Squared = .841 (Adjusted R Squared = -.435)
2. R Squared = 1.000 (Adjusted R Squared = 1.000) Annual Energy Consumption per Unit Area

Annual Energy Consumption per Student

**H3:** Higher degrees of differences appear between students’ comfort levels in schools with low energy consumption, building transparencies and compactness than schools with high energy consumption, building transparencies and compactness when the attended number of lessons increases.

When the number of attended lessons increase, it is possible that students develop higher levels of discomfort and complaints such as feeling tired, poor air quality, unpleasant odor or distraction. Similarly, thermal discomfort is a reason for sick building syndrome symptoms, complaints and distraction along with poor indoor air quality causing poor performance (Wargocki & Wyon, 2007b). The research focuses on whether the gap between students’ comfort levels in the first and last lessons are wider in lower energy consuming schools than the one in higher energy consuming schools. Items 16-23 in the questionnaire are related to students’ comfort levels in their classrooms.

The null hypothesis:

H0:  students’ comfort level differences between the first and last three lessons in schools with low energy consumption, building transparencies and compactness =  students’ comfort level differences between the first and last three lessons in schools with high energy consumption, building transparencies and compactness

The alternate hypothesis:

HA:  students’ comfort level differences between the first and last three lessons in schools with low energy consumption, building transparencies and compactness ≠  students’ comfort level differences between the first and last three lessons in schools with high energy consumption, building transparencies and compactness

The items 16-23 in the research questionnaire are directly linked to students’ well-

being. The other items under the subtitle ‘Well-being’ are more related to outdoor effects. The research results show that students’ complaint level in the first three lessons

is 47.55% while it is 55.65% in the last three lessons in MINECSs. The same figures in MAXECSs are 30.42% and 34.79%, respectively. Students’ complaint levels increase by 8.1% in MINECSs while they increase by 4.37% in MAXECSs. It shows that complaint level differences between the first three and last three lessons changes 3.73% more in MINECSs than MAXECSs. Thus, it can be derived from the results that students in MINECSs are more affected when the number of lessons is increased than the students in MAXECSs. The results reject the null hypothesis with a Chi-square statistic of 366.069, a *p*-value of 0.0 and Yates’ *p*-value of 0.0 at *p<.05*. Thus, there is statistically significant change between students’ comfort levels in MINECSs and MAXECSs when the attended number of lessons is increased. Likewise, one-way Anova results with the *f*-ratio value of 18.69148 and *p*-value of 0.00001 at *p*<.05 indicates significance. Table 34 and Table 35 below show Chi-square and Anova results, respectively.

Table 34: Chi-square test results for number of attended lessons and students’ complaint levels

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Value | degrees of freedom | *p*-value | Yates' chi-square | Yates'  *p*-value |
| Chi-Square | 366.069 | 3 | 0.0 | 364.358 | 0.0 |

Table 35: One-way Anova results for number of attended lessons and students’ complaint levels

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | 1.4627 | 3 | 0.4876 | 18.69148 | 0.00001 |
| Within Groups | 18.4946 | 709 | 0.0261 |  |  |
| Total | 19.9573 | 712 |  |  |  |

Thus, the results of Chi-square and one-way Anova show that higher degrees of differences appear between students’ comfort levels in low energy consuming schools than high energy consuming schools when the attended number of lessons increases.

**H4:** Students in schools with low energy consumption, building transparencies and compactness have higher levels of health problems than students in schools with high energy consumption, building transparencies and compactness.

As school children are more vulnerable to unfavorable conditions than adults, energy consumption that affects indoor environmental conditions can be of importance from the point of students’ health. Shaikh et. al. (2013) draws attention to the impact of indoor comfort on occupant’s health while Clements-Croome (2006) states that students’ thermal comfort and needs could play a significant role on their health and well-being.

The null hypothesis:

H0:  level of students’ health problems in schools with low energy consumption, building transparencies and compactness =  level of students’ health problems in schools with high energy consumption, building transparencies and compactness

The alternate hypothesis:

HA:  level of students’ health problems in schools with low energy consumption, building transparencies and compactness ≠ level of students’ health problems in schools with high energy consumption, building transparencies and compactness

The items 4-15 in the research questionnaire are listed under the subtitle ‘Health – How are you today’. The research results show that 26.8% of students complain about their health in MINECSs while the same percentage is 21.1% in MAXECSs. That means the students in MINECSs complain by 5.7% more about their health in MINECSs than the students in MAXECSs. The results reject the null hypothesis with a Chi-square statistic of 37.647, a *p*-value of 0.0 and Yates’ *p*-value of 0.0 at *p<.05*. Thus, there is statistically significant difference between students’ health levels in MINECSs and MAXECSs. Also, one-way Anova results with the *f*-ratio value of 14.10443 and *p*-value of 0.00019

at *p*<.05 indicates significance. Table 36 and Table 37 below show Chi-square and Anova results, respectively.

Table 36: Chi-square test results for the items concerning students’ health (Items 4-15)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Value | degrees of freedom | *p*-value | Yates' chi-square | Yates'  *p*-value |
| Chi-Square | 37.647 | 1 | 0.0 | 37.336 | 0.0 |

Table 37: One-way Anova results for the items concerning students’ health (Items 4-15)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | 0.5655 | 1 | 0.5655 | 14.10443 | 0.000187 |
| Within Groups | 0.3508 | 22 | 0.0159 |  |  |
| Total | 0.37 | 23 |  |  |  |

Thus, the results of Chi-square and one-way Anova show that students in lower energy consuming schools have higher levels of health problems than students in higher energy consuming schools.

**H5:** Students in schools with low energy consumption, building transparencies and compactness have higher levels of distraction than students in schools with high energy consumption, building transparencies and compactness.

Many factors can lead to distraction or lack of concentration during lessons. Bakó-Biró et al.’s (2012) state that unfavorable environmental conditions can lower people’s level of concentration. School children can be more affected by negative classroom conditions and the difference in annual energy consumptions per unit area might be one of the factors that play a role in students’ distraction.

The null hypothesis:

H0:  students’ levels of distraction in schools with low energy consumption, building transparencies and compactness =  students’ levels of distraction in schools with high energy consumption, building transparencies and compactness

The alternate hypothesis:

HA:  students’ levels of distraction in schools with low energy consumption, building transparencies and compactness ≠ students’ levels of distraction in schools with high energy consumption, building transparencies and compactness

Items 25-28 in the applied questionnaire are directly concerned about students’ distraction and they have been taken into consideration for the analysis. According to the results of the research, 30.68% of responses indicated a presence of distraction in MINECS classrooms while the same figure was 22.6% in MAXECS classrooms. It means that the students in low energy consuming schools experience 8.08% more distraction than the ones in high energy consuming schools. The results reject the null hypothesis with a Chi-square statistic of 24.008, a *p*-value of 0.000001 and Yates’ *p*- value of 0.000001 at *p<.05*. Thus, there is statistically significant difference between students’ levels of distraction in MINECSs and MAXECSs. Correspondingly, one-way Anova results with the *f*-ratio value of 29.7417 and *p*-value of 0.00001 at *p*<.05 indicates significance. Table 38 and Table 39 below show Chi-square and Anova results, respectively.

Table 38: Chi-square test results for the items concerning students’ distraction (Items 25-28)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Value | degrees of freedom | *p*-value | Yates' chi-square | Yates'  *p*-value |
| Chi-Square | 24.008 | 1 | 0.00000096 | 23.594 | 0.00000119 |

Table 39: One-way Anova results for the items concerning students’ distraction (Items 25-28)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | 1.2863 | 1 | 1.2863 | 29.7417 | 0.00001 |
| Within Groups | 30.7056 | 710 | 0.0432 |  |  |
| Total | 31.9919 | 711 |  |  |  |

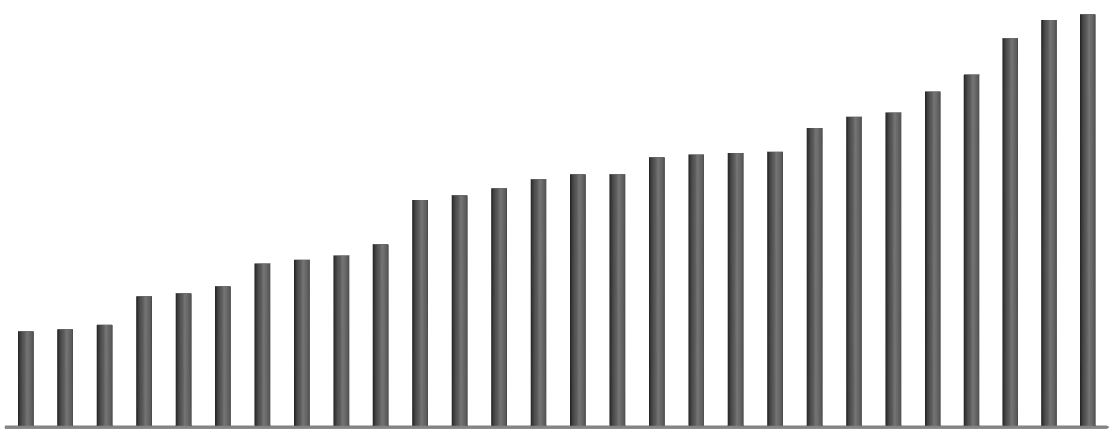
Thus, the results show that students in lower energy consuming schools experience higher levels of distraction problems than students in higher energy consuming schools.

## 4.2 Conclusions, Discussion and Recommendations

There two stages of the thesis and the first stage deals with energy saving school features from the point of annual energy consumption per unit area while the second one deals with the differences in students’ comfort levels from the point of students’ health, well-being and distraction between schools with low energy consumption, building transparencies and compactness than schools with high energy consumption, building transparencies and compactness.

The research results show that the annual energy consumptions of the state primary and secondary schools in PCM are lower than previous years and much lower than neighboring countries and European countries in general. The effect of Termokos Central Heating System cannot be denied in case of Central Pristina state primary and secondary schools with an annual average of 708.1 kWh/student, 69.4 kWh/m2, 13.7 kgCO2/m2 and 0.15 students per meter square according to the results of the research calculations of this thesis. The same averages were calculated as 671.7 kWh/student, 107.0 kWh/m2 and 15.4 kgCO2/m2, respectively for the pre-primary state schools with

an average of 0.15 students per meter square in the same Municipality. However, Pristina does not reflect the national averages as the same averages calculated for the state schools in Vushturi Municipality with an average of 0.21 students per meter square were 823.4 kWh/student, 176.3 kWh/m2 and 48.4 kgCO2/m2, respectively. Comparison of the results with the neighboring and other European countries for annual energy consumption per meter square is given in Figure 14 below.



68

69.4

72.6

93

95

100

116.22

119

122

130

161.6

165

170

176.3

180

180

192

194

195

196

213

221

224

239

251

277

290

294

Figure 14: Comparison of the annual average energy consumption of state primary and secondary schools in PCM with the school averages of the neighboring and the other European countries

Greece (6)

Pristina\* Albania (1)

Luxemburg (17)

Denmark (10)

Montenegro (15)

Cyprus (11)

Northern Ireland (18)

Spain (3)

Bulgaria (5)

Kosovo (13)

Sweden (5)

Finland (9) Kosovo (Vushturi)\* Kosovo (Standard) (12)

Italy (2)

Slovenia (4)

Germany (5)

Ireland (5)

Belgium (5)

Netherlands (5)

UK (4)

France (Paris) (7)

Slovakia (8)

Austria (5)

Macedonia (Pechevo) (16)

Serbia (14)

Czech R. (5)

(Sources: \* The author’s research results, 1 (AAIE, 2015), 2 (Zinzi et al., 2015), 3

(Gaitani et al., 2015), 4 (Airaksinen, 2011), 5 (Birchall et al., 2014), 6 (Vourdoubas,

2016), 7 (Mairie de Paris, 2012), 8 (Maldonado, 2013), 9 (Pereira et al., 2014) 10

(Maldonado, 2012), 11 (Katafygiotou & Serghides, 2014), 12 (IEA, 2015), 13 (World

Bank, 2013), 14 (Todorovic, 2015), 15 (UNECE, n.d.), 16 (USAID, 2015), 17 (Thewes

et al,. 2014), 18 (Jones et al., 2000)

The average annual school energy consumptions (kWh/m2/yr) in Europa range between 68 in Greece and 294 in Czech Republic. In neighboring countries, it changes between

* 1. in secondary schools and 72.6 in high schools in Albania to 290 in Serbia. The annual average energy consumption of Central Pristina state primary and secondary schools appears to be the second lowest value in all Europa according to literature. However, the average of state schools in Vushturi and all Kosovo are more like in the middle.

When it comes to the school level, the research results can serve city administrators, planners/designers, school administrators and researchers for the design of school buildings that are going to be built and that already exist. The results of the first stage of the thesis research as energy saving school features for annual energy consumption “for unit area” and their energy saving percentages according to the averages can be summarized as given below:

* + - Double shifts (morning and afternoon) – 40.3%
    - Built in 2000 or later – 28.3%
    - One-building – 4.2%
    - Multi-floor – 57.2%
    - More than 1000 students – 37.2%
    - Bigger than 1000 m2 total building area at least – 29.3%
    - Without energy source of wood and coal – 16.4%
    - With less than 0.2 st/m2 student density – 22.8%

The only school in PCM that fits the above-mentioned features, Sami Frasheri 2, spends

19.3 kWh/m2/yr of energy and it saves 72.2% energy in comparison with the Municipality average, 69.4 kWh/m2/yr. It is clear that it will also save great amount of the Municipality budget and will pay back earlier than World Bank Groups’ calculation of 5.6 years with 53% of energy consumption saving.

From the point of the research hypotheses, study shift as morning and morning + afternoon, number of school building floors and student density (student/m2) claiming that they are statistically significant predictors for annual school energy consumption per student (kWh/st/yr) and unit area (kWh/m2/yr), annual CO2 emission per unit area

(kg CO2/m2/yr) are proven to be statistically significant. According to the results and

analyses of the research Hypothesis 1, student density and study shift, separately and combined together, statistically significant factors on annual school energy consumption per student (kWh/st/yr), annual school energy consumption per unit area (kWh/m2/yr) and annual CO2 emission per unit area (kg CO2/m2/yr). In addition, number of school building floors significantly affects annual energy consumption per unit area while mean scores for annual energy consumption per student statistically significantly different between 1 and 2 building floors but not between 2 and 3 building floors. It is clear that annual school energy consumption per student and student density are directly related issues, at least as a matter of calculation. Also, study shift may affect student

density as students are separated into different shifts and prolong school buildings’ functioning hours. There might be several reasons to explain the relation between umber of school building floors and annual energy consumption per unit area. Energy exchange between floors may help each other to warm up. Thus, these findings align with previous findings of other researchers.

It can be derived from the above-mentioned results that student density can be a very crucial factor from the point of school building energy consumption as there are sharp differences between the annual energy consumptions with less and more than 0.2 st/m2 student densities of state schools both in Pristina and Vushturi. Bigger schools have lower energy consumption figures per unit area as the nature of calculation. However, it is debatable that bigger sizes make a school more energy efficient. Hence, when the energy efficiency standards are set for buildings, specifically school buildings, the standards should also provide figures concerning annual energy consumption per student and a balance among them should be built. Furthermore, different indicators can

be used for different purposes. For instance, when students’ comfort is the main concern, using annual energy consumptions per student can provide more realistic solutions. Thus, further and more-in-depth researches concerning the relations between building energy consumption and people’s comfort from the point of student density can be carried out. In the case of the state primary and secondary schools in PCM, according to the calculations of the first stage, the student densities vary from 0.01 to

* 1. and it is a very big gap for a city, let alone a small one. While it is a long-term procedure to replace old schools with new and more energy efficient ones, student density can be adjusted/balanced to some extent for the benefits of energy consumption and student comfort. However, it is worth noting that although large schools with a population of more than average can consume less energy per meter square and student, overcrowded and huge schools may have negative impacts on students’ psychology specifically on younger ones.

Schools with a priority of renovation can be determined and start renovations according to that priority, students’ complaint level, student density and energy consumption figures. Finally, Kosovo is a country with a population of 1861000 in 2016, with a sharply decreasing annual population growth percentage and its population will be around 2223000 in 2050 (bluemarblecitizen, n.d.). Apparently, the population will not change much in the following years and there will not be much need to build new school buildings in near future. However, old school buildings are gradually replaced with newer ones. The research results can be used to find out what makes some schools consume less energy than the others.

Furthermore, annual school energy consumption per student, annual school energy consumption per meter square and annual CO2 emission per meter square are not statistically significant predictors for each other. The findings fit the results of previous studies as fuel type, quality and efficiency play more significant roles on CO2 emission, and student density or/and number of students is not taken into account for heating purposes. However, a study can be carried out to find at least a balance among these three indicators and finding the right fuel type can be crucial in this process. For instance, according to the research results of this thesis, schools that use oil as an energy source in PCM consume less annual energy per the unit area than schools that use wood. However, again according to the research results, schools that use oil fuel produce much more CO2 emission than the ones that use wood. The same goes for the state schools in Vushturi. CO2 emission is directly related to environment, students’ health and environmental comfort. A balance between energy sources can be built and maintained with the help of EMSs to keeping a track of energy consumption per unit area and student, and CO2 emission. The right fuel type should also be assessed from the point of students’ comfort. (Nearly) zero energy buildings can also throw lights into the issue.

Naturally, there are innumerous factors that affect school energy consumption and CO2 emission and the research of this thesis takes a few of them into consideration as it is impossible to take all at once. Some factors and their effects on energy consumption can be simple and straightforward such as students’ shift while some others such as building age can be a more complicated issue because material and school design used in a particular period may have their own peculiarities, number of school buildings due to transparency and compactness effects, or school shape and design, neighboring environment and shadowing at different times of the day. Moreover, there are several school building groups and types that may affect the results. For instance, universities and boarding schools present totally different energy consumption patterns and they can be less predictable. Furthermore, state and private schools can present differences as private schools in general are better equipped as they are a part of business. The study of this research was limited to the state primary and secondary schools in PCM. Finally, a comparison between overall energy efficiency of schools with a central and separate heating systems can help city administrations to make better decisions.

Although practices based on natural applications can be preferable in most cases, it is almost impossible to have a healthy and well-balanced environment under unfavorable conditions such as cold and hot seasons, and for all students such as students sitting near the wall or windows and at the back or in front of their classrooms. Justice in education requires at least favorable environmental conditions for all. Thus, the second stage of the thesis research basically aims to find out the differences in comfort levels of students who study in schools with low energy consumption, building transparencies and compactness (MINECSs) and students who study in schools with high energy consumption, building transparencies and compactness (MAXECSs) since energy consumption averages are meaningless without occupants’ comfort. The research also compares students’ comfort levels under several subcategories between these two groups of state primary and secondary schools in the Pristina Central Municipality to find out the effects of school energy consumptions on students’ health, well-being and distraction. The research hypotheses suppose that there are differences between students’ health and distraction levels in MINECSs and MAXECSs along with claim that higher degrees of differences appear between students’ comfort levels in MINECSs and MAXECSs when the attended number of lessons increases.

From the point of the research hypotheses, in comparison with the students in MAXECSs, the students in MINECSs;

* + - Experience 3.73% higher levels of differences in their well-beings when the attended number of lessons increase,
    - Have 5.7% more problems concerning their health,
    - Feel 8.1% more distracted.

As a matter of nature, energy consumption is not the only factor that affects students’ health, well-being and distraction and there are several other factors such individual and regional facts. However, the analyses applied for this research verify the research hypotheses that support previous studies.

Based on the research results, students in the researched schools mostly complain about indoor temperature and air quality. For instance, students in low energy consuming schools complain about both dry and hot air in spring time (45.5%) and cold classrooms in winter (75%) along with poor air (65.9%) and unpleasant smell (52.3%). Thus, energy renovation of school buildings can be carried out according to high percentages in students’ complaint levels.

Again, according to the research results of the second stage, the highest complaint differences between the students of MINECSs and MAXECSs appear in classroom temperatures in winter, air quality as poor and unpleasant odor, and disturbance from outside as noise and sun heat. Furthermore, students affected at the highest levels by the energy consumption differences are the ones sitting near:

* + - Windows at the back of their classrooms at the first three lessons
    - The wall in front of their classrooms at the first three lessons
    - Windows in front of their classrooms at the last three lessons.

On the other side, students near the wall at the back of their classrooms are the ones that are affected at the lowest levels by the differences in energy consumptions. As the school buildings already exist, the gap between the groups of schools and the complaint levels of their students can be closed by the measures of insulation that directly alter building energy consumption and by the well-positioned installation of thermal air quality appliances, specifically air conditioners, and lighting appliances. It is understandable from the results of the sub-categories that most disturbed students sit at the corners of their classrooms. Thus, appliances to improve school indoor environment should be distributed across the classroom instead of one appliance located in one place. For instance, instead of one light bulb several light bulbs or florescent lamps, or an air condition system that distributes fresh air with holes in different parts of the classroom. That the items with the highest complaint levels are related to classroom temperature, odor and disturbance from outside heat shows that air conditioning is the first concern to enhance students’ indoor comfort. Furthermore, the comfort level differences in sub- categories show that average school energy consumption figures are not significant or sufficient to estimate each student’s indoor comfort.

Students specifically in MINECSs often complain about disturbance from outside noise and sunlight. Basically, the solution is related to the structure and direction of the school. The issue can also be related to the size of school yard. A study concerning correlation between school yards, school energy consumption and students’ comfort could provide valuable information.

Moreover, students’ health and well-being should not be considered as only physical health and well-being. Therefore, questionnaires on students’ health and well-being should combine physical, mental and psychological aspects. A questionnaire with various aspects could provide better insight of energy consumption practices on students’ health and well-being. Likewise, this thesis deals with two aspects of energy consumption in schools as energy saving school features and students’ comfort. However, a study including aspects of students’ and administration’s energy behavior as the third stage could make the research more inclusive. Besides, a study concerning the optimum ratio between building transparency and compactness on school environmental quality and students comfort, specifically visual one could open new doors on building design. Finally, a research on students’ comfort levels according to annual energy consumption per unit area, per student and student density could be carried out to compare the results.

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# Appendices

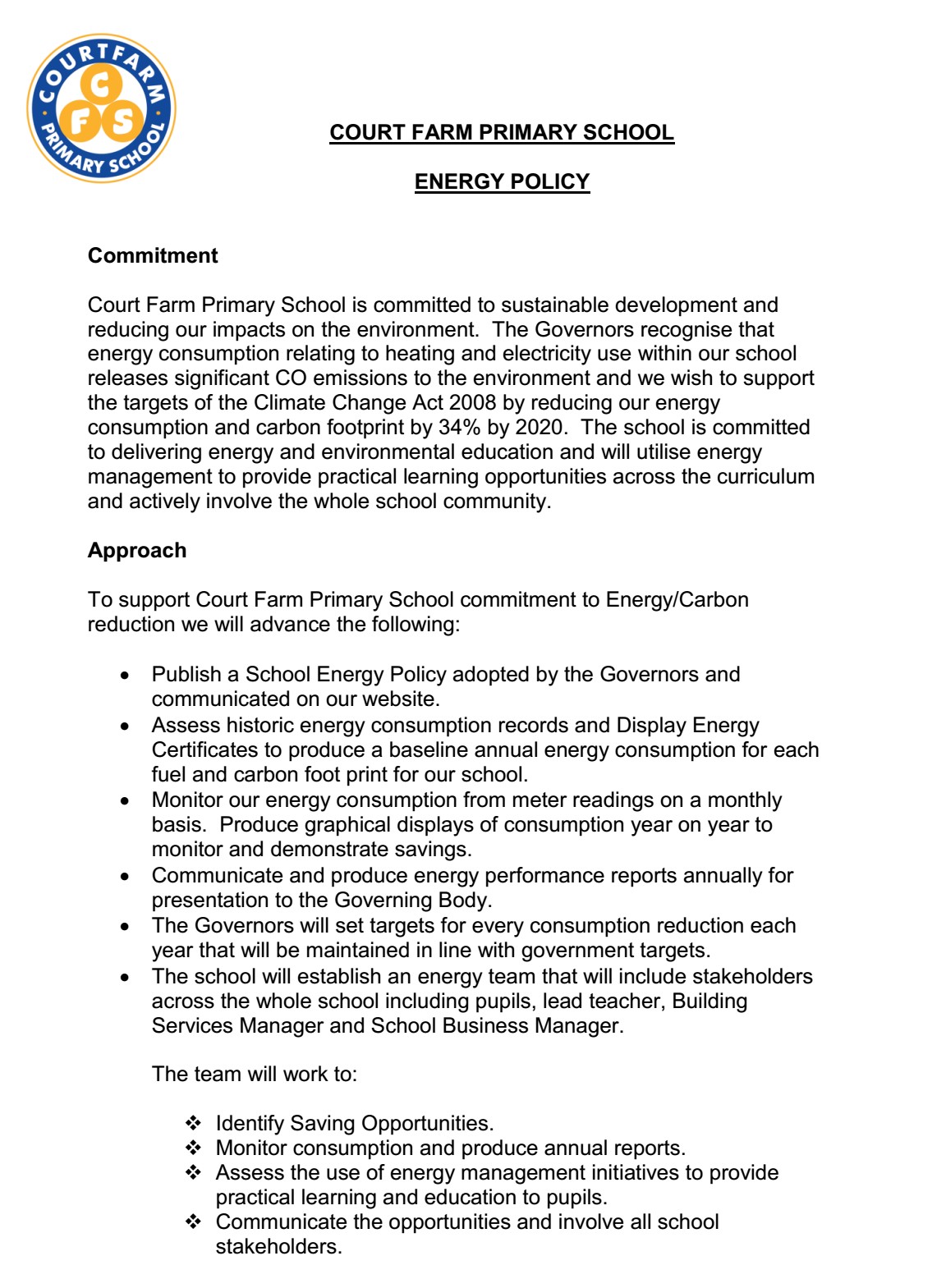
**Appendix A.** Örebro Questionnaire and the average complaint percentages for the MINECSs and the MAXECSs energy consuming state schools in PCM.

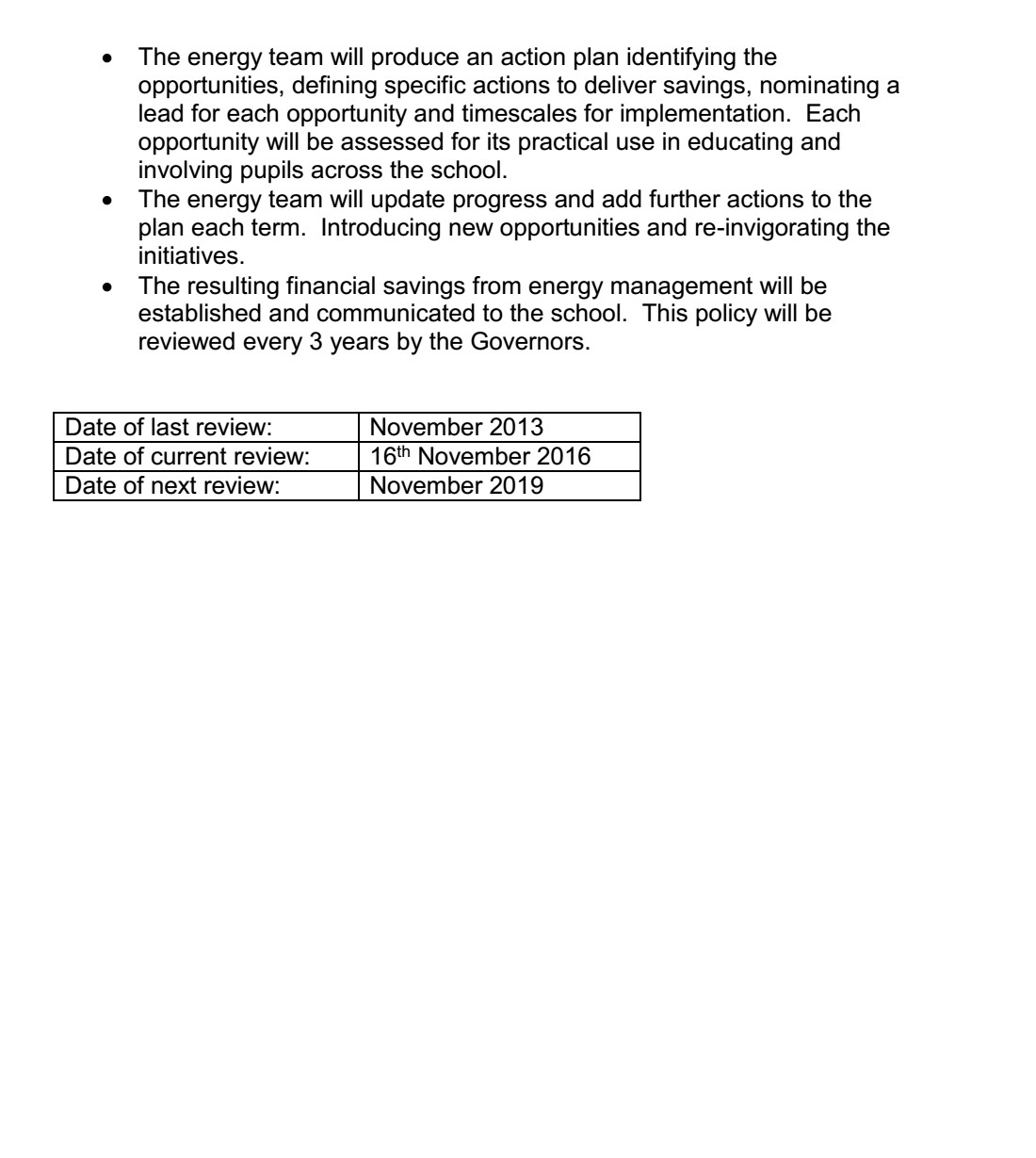
|  |  |  |
| --- | --- | --- |
| Örebro Questionnaire Items | Percentages (%) | |
| MAXECSs | MINECSs |
| HEALTH - How are you today ? |  | |
| 4. Are you tired? | 41.3 | 54.5 |
| 5. Does your head feel heavy? | 37.5 | 43.8 |
| 6. Do you have a headache? | 28.8 | 35.8 |
| 7. Do you feel faint (lightheaded) or dizzy? | 19.6 | 23.9 |
| 8. Do you have trouble concentrating? | 27.9 | 38.6 |
| 9. Do your eyes itch or sting? | 23.8 | 31.3 |
| 10. Are you hoarse or dry in the throat? | 17.5 | 23.3 |
| 11. Do you have a runny or stuffy nose? | 12.5 | 11.9 |
| 12. Do you have a cough? | 7.5 | 13.1 |
| 13. Do you have a cold? | 10 | 11.4 |
| 14. Do your hands or face itch? | 10.8 | 12.5 |
| 15. Are you sick or unwell in any other way? | 16.7 | 21.6 |
| WELL-BEING - What is it like in the classroom today? |  | |
| 16. Is it too hot? | 28.8 | 45.5 |
| 17. Does the heat/temperature from the Sun disturb? | 44.6 | 65.3 |
| 18. Do you feel cold in the classroom in WINTER? | 45.4 | 75 |
| 19. Do you feel the draft on your feet or on your neck? | 13.8 | 13.6 |
| 20. Are you plagued (affected negatively) by changing the temperature in the room? | 31.3 | 44.3 |
| 21. Does the air feel heavy or poor (bad)? | 39.2 | 65.9 |

|  |  |  |
| --- | --- | --- |
| 22. Does the air feel dry? | 27.5 | 45.5 |
| 23. Are there any unpleasant odors (smell)? | 31.7 | 52.3 |
| 24. Is it hard to hear what is being said in the classroom? | 22.5 | 31.8 |
| 25. Is there distracting noise or disturbance from the students in the class? | 43.3 | 38.6 |
| 26. Is there disturbing noise from the students or teachers of other classes or classrooms? | 16.7 | 30.7 |
| 27. Is there distracting noise outdoors (from the traffic/schoolyard/ construction, or the like)? | 22.5 | 43.2 |
| 28. Is there distracting hiss or noise from ventilation or other things in the building? | 7.9 | 11.9 |
| 29. Is the light good enough at your workplace? | 84.6 | 80.7 |
| 30. Is there reflection from the blackboard? | 37.1 | 42.6 |
| 31. Is there annoying light from the Sun? | 40 | 57.4 |
| 32. Have you received an electric shock when touched by something (static electricity)? | 15.4 | 21.6 |
| 33. Is it clean enough in the classroom? | 73.3 | 38.1 |
| 34. Do you enjoy well in school? | 88.8 | 86.4 |
| OTHER CONDITIONS |  | |
| 35. Do you have trouble seeing what's on the board (even if you use glasses)? | 19.2 | 23.3 |
| 36. Have you eaten anything today? | 68.8 | 58.6 |
| 37. Do you have asthma? | 29 | 40 |
| 38. Do you have allergies bothering? | 14.2 | 22.2 |
| 39. Do you use regular medication for asthma or allergies? | 5.8 | 10.2 |
| HOME CONDITIONS |  | |
| 40. Do you share your bedroom with any brothers, sisters or anyone? | 67.5 | 68.8 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 41. Do you have carpet that covers the entire floor in your bedroom (wall-to-wall blanket)? | | | | 46.3 | 40.9 |
| 42. Is your bedroom well ventilated at night (open window, or the equivalent good aeration)? | | | | 90.4 | 94.9 |
| 43. Do you live with someone who smokes? | | | | 47.6 | 54 |
| 44. Do you have a pet at home? | | | | 23.8 | 18.8 |
| 45. Do you have regular contact with other animals/pets? | | | | 16.3 | 18.2 |
| ENVIRONMENTAL SURVEY | | | |  | |
| How do you perceive the air quality now? | | | |
| Very good (clearly acceptable)  - Score as 1 | A little bit of good (as far as acceptable)  - Score as 2 | A little bit poor (as far as unacceptable)  - Score as 3 | Very bad (clearly unacceptable)  - Score as 4 | 2.07 | 2.42 |

**Appendix B.** A Sample Primary School Energy Policy (Court Farm Primary School, 2014).





**Appendix C:** Key Elements and Potential Changes in the Kosovo Legislative Framework (World Bank Groups, 2016)

The major elements of the existing primary and secondary legislation relevant to EE implementation are summarized below:

|  |  |
| --- | --- |
| **Law on Energy Efficiency** | Obligates MoED and municipalities to prepare EE action plans and set up the EE Agency and fund EE initiatives.  As far as public building stock is concerned, the Law sets new responsibilities for municipalities regarding energy efficiency, water management, and other related issues. In addition, the law states that the energy and water responsibilities associated with educational institutions, public health organizations, and social services, along with environmental protection, should be shared between municipal and central authorities. The municipality is also responsible for the design and implementation of regional policies related to energy, water, and other issues, as they are an important attribute to national energy policies.  A notable deficiency within the Law is that it does not provide incentive measures for efficient energy consumers nor does it enforce penalty provisions for failing to comply with the Law or for disregarding EE objectives. Furthermore, the Law foresees an Energy audit as a systematic procedure to obtain: (i) adequate knowledge of the existing energy consumption profile of a building or group of buildings, of an industrial operation, or of a private or public service; (ii) identification of opportunities for cost-effective energy savings; and (iii) reports on the findings. |
| **Kosovo Energy Efficiency Agency** | Established in 2011 to implement the Law on Energy Efficiency. Headed up by a Chief Executive Officer and consists of 3 divisions: the Planning Division, the Promotion and Project Development Division, and the Monitoring and Reporting Division |
| **NEEAP 2010-2018** | As committed under the Energy Community Treaty, indicative targets for EE savings set at 9% by 2018; updated every 3 years. |
| **Law on Energy** | Approved in October 2010: Determines EE targets, encourages advanced metering systems, provides EE policy framework and subsequent implementation.  Regarding buildings, this law states that the Ministry should, among other things, foster improvements in the energy efficiency level of buildings, and establish requirements for energy efficiency certification of buildings. |

|  |  |
| --- | --- |
| **Law on Construction** | Contains important features related to energy performance of buildings including building code norms for new and renovation projects, implementation of EE measures, and certificate of compliance with EE measures. |
| **Law on PPP and Concessions** | States that the duration of a Public-Private Partnership shall be set forth in the corresponding Agreement, and that duration of a Public- Private Partnership shall be reasonably related to and reflect: (i) the life-cycle of the public infrastructure; (ii) rate of return and (iii) value-for-money of each individual Public-Private Partnership Project.  Regarding financial rights, the law stipulates that a Private Partner shall have the right to charge, receive or collect tariffs, fees and any other charges for the use of the Public Infrastructure or the provision of public services in accordance with the terms and conditions set forth in the respective Agreement. |
| **Municipal Energy Efficiency Plans (MEEP)** | Under the Law on EE, Municipal Energy Offices are required to develop Municipal EE Plans and Implementation Progress Reports. The overall objective of municipal EE plans is to reduce energy consumption in the building stock, transport and public lighting, and in the operation of municipal services by reducing the burden of energy costs on municipal budgets. Hence, the MEEP is expected to impact the municipality through:   * improvement of municipal services; * reducing energy costs in the municipal budget; * renovation of energy systems and buildings; * improving the sanitary conditions and increased productivity; * raising awareness of the energy saving policy-makers, operators, and end-users.   Nevertheless, municipalities are currently not allowed to take loans as they do not meet the criteria stipulated in the Law on Loans. The central government, however, has allowed municipalities to obtain loans for implementing EE measures, in order to meet the KEEAP requirements. |
| **Secondary Legislation** | Series of secondary legislation adopted (e.g., appliance labeling, energy auditing, etc.). |

These laws and subsequent legal acts are being implemented by a number of actors, which in many cases are supported by donors. However, all actions related to the Law on EE and the related secondary legislation are overseen and regulated by government authorities. These authorities and their respective roles are summarized below:

* + - Kosovo Energy Efficiency Agency (KEEA) (under the Ministry of Economic Development): responsible for the implementation of Kosovo’s plan on energy efficiency, as well as for reporting on the implementation of the agreed targets.
    - Energy Regulatory Office (ERO): independent body reporting to the Kosovo Assembly; responsible for monitoring the energy market development; encouraging energy efficiency among market players; ensuring protection of customers including vulnerable customers.
    - Ministry of Economic Development (MED): responsible for preparing the Kosovo energy strategy and policies for energy efficiency and renewable energy.
    - Ministry of Environment and Spatial Planning (MESP): responsible for implementing the directive on energy performance in buildings.
    - Ministry of Local Government Administration (MLGA) and Association of Kosovo Municipalities: responsible for improving energy data quality and for ensuring energy efficiency planning and implementation at local levels, as well as promoting renewable energy projects in their respective municipalities.
    - Ministry of Trade and Industry (MTI): responsible for ensuring the implementation of the legislation on biofuels in accordance with the Energy Community requirements.

## Potential Changes in the Legislative Framework

The existing laws and institutional mechanisms exemplify the efforts of Kosovar authorities towards implementing energy efficiency. The Government of Kosovo (GOK) has developed institutional and regulatory frameworks for EE and renewable energy. Additionally, GOK has worked to streamline and better regulate implementation effort by declaring secondary legislation and developing rulebooks, financing mechanisms, and other implementation elements, all of which were absent until recent years.

The current status of EE in Kosovo has been shaped primarily by the provisions of Kosovo’s current Law on Energy Efficiency. This Law, however, is presently under

review and is expected to change substantially during the course of 2016. As a result, Kosovo’s EE situation and circumstances are expected to modify accordingly. The new law is expected make way for the launch of an Energy Efficiency Fund, which will be initiated with a governmental grant, and then seek loans from international financial institutions (IFIs) and other sources. The legal precedence and justification for this fund derives from Article 52 of Directive 2012/27/EU, which specifies that “the financing facilities could in particular use those contributions, resources and revenues to enable and encourage private capital investment, in particular drawing on institutional investors.”

Additionally, Chapter 8, Article 16 of Kosovo’s Draft Law on Energy Performance of Buildings legally supports and foresees the presence of an EE fund by stating that “all funds collected from fines imposed based on this Law shall be transferred to the Fund on Energy Efficiency or, in the absence of such a Fund, to the Budget of the Republic of Kosovo.” Three pre-feasibility studies, aimed at analyzing respectively the legal, technical, and financial terms for starting the fund were recently conducted by the MED and KEEA.

However, these studies have not yet been published.

Despite the comprehensive legal framework, many challenges remain within the implementation and regulatory processes as well as for the implementing actors and governing entities. For example, in recent years KEEA has undertaken many tasks and activities related to its main task of implementing the Law on Energy Efficiency and preparing the 1st and 2nd NEEAPs; however, it has limited technical and almost no implementation capacities. This shortfall can be largely attributed to the inadequate budget/staffing the agency is coping with while adhering to its responsibilities. At the municipal level, EE improvements through MEEAPs are also encountering implementation difficulties due to insufficient access to financing. The public sector suffers from a range of procedural barriers, from budgeting to procurement, which tend to be rigid in nature and prevent many EE improvements from being realized.

The Energy Regulatory Office of Kosovo has increased energy prices, roughly 3.1% annually, from 2007 through 2015 for an approximate total increase of 27.9%. However, there have been few indications that such increases in energy costs have yielded positive impacts on EE levels. Kosovo has not developed a comprehensive communication strategy for promoting the benefits of EE throughout the country, nor has it established incentives in the promotion and compliance processes. There are, nevertheless, several positive incentive measures currently in the implementation phase. For example, loans with low interest rates have been introduced for individuals and companies that have EE projects.

**Appendix D:** Energy Efficiency Barrier Matrix for Public Sector in Kosovo (World Bank, 2013).

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| **Legal and Regulatory** | **Financial** |
| * **Barrier Public Legal and Regulatory (PLR)1:** Budgetary rules do not allow municipalities to benefit from any energy savings they achieve in the longer term – whilst other national grants to municipalities are awarded according to set formulae, each year’s budget allocation for utility bills is based on the previous year’s outturn. Any savings achieved in energy costs may not be used to finance investments. * **Impact:** Reduced incentive to invest in EE measures.   Barrier to operation of Energy Serving Companies (ESCOs)   * **Remedy:** Research possibility of making changes to the municipal budget setting process or of circumventing this constraint * **Responsibility:** GoK, Ministry of Finance (MoF) | * **Barrier Public Financial (PF)1:** The Law on Public Debt imposes various restrictions on municipalities’ ability to borrow money, principally the need to have two   consecutive years of unqualified accounts   * **Impact:** Cash strapped municipalities cannot borrow in order to finance EE projects * **Remedy:** Deliver funds to municipalities via other channels, such as central government (via appropriate ministries) until borrowing criteria met * **Responsibility:** IFIs, GoK, MoF, KEEA |
| * **Barrier PLR2:** Energy savings may be deferred due to compliance with Technical Regulation Nr. 03/2009, which states that ‘energy sustainability’ requires achievement of planned comfort levels in public buildings, as well as energy efficiency * **Impact:** Achieving comfort levels in some public buildings may initially increase energy consumption and energy costs, even if accompanied by implementation of EE measures; ESCO type arrangements cannot be applied in such a situation * **Remedy:** Develop schemes to provide financial assistance to help public buildings meet minimum legal comfort levels * **Responsibility:** IFIs, Ministries, municipalities | * **Barrier PF2:** Central government budgetary constraints limit investment opportunities., particularly in the current economic climate * **Impact:** Central government cannot finance EE projects * **Remedy:** Secure funding from IFIs * **Responsibility:** IFIs, GoK, MoF, KEEA |

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| * **Barrier PLR3:** The Law on Public Procurement requires government tenders to take account of positive EE related aspects.   But it is not being implemented because the necessary secondary legislation not in place.   * **Impact:** Tenders are evaluated purely on the basis of gross cost and the value of the energy saving potential of bids is ignored, * **Remedy:** The secondary legislation required to implement the amendments to the Public Procurement Law has to be drafted and enforced. * **Responsibility:** MoF |  |

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| **Economic** | **Institutional** |
| * **Barrier Public Economic (PE)1:** EE is not a top priority for municipality mayors - water supply, waste disposal, sewage treatment are considered more important * **Impact:** Any available funds are spent on other projects, even though EE programs can have a better Return on Investment (ROI) than other priorities * **Remedy:** Set up dedicated funding facilities which can only be used for EE related investments * **Responsibility:** IFIs, KEEA, municipalities | * **Barrier Public Institutional (PI)1:** The demands of the decentralization process place an increasing burden on municipalities while their resources are frozen or being reduced. There is insufficient EE expertise and insufficient resources at municipal level * **Impact:** Municipal EE planning and implementation are constrained and municipalities cannot deliver good quality EE plans * **Remedy:** Consider changing the basis for EE planning to a regional level (e.g. based on the Regional Development Agency structure). Training Agency to provide training to municipalities and to assist with setting up of EE planning support facility at regional level (being addressed by an EU funded project) * **Responsibility:** IFIs, KEEA, municipalities |

**Appendix E:** Questionnaire to Determine Energy Consumption in Buildings (World Bank, 2013).

