İSTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

ENERGY SAVINGS OF PRIMARY SCHOOL BUILDINGS IN TURKEY THROUGH ENERGY EFFICIENT RENOVATION STRATEGIES IN BUILDING ENVELOPE

M.Sc. Thesis by

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Programme : Environmental Control and Structural Technologies

JUNE 2009

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<u>**İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ**</u>

TÜRKİYE'DEKİ İLKÖĞRETİM BİNALARINDA BİNA KABUĞUNDAKİ ENERJİ ETKİN İYİLEŞTİRME YÖNTEMLERİYLE ENERJİ KAZANÇLARI

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FOREWORD

One of the vital problems for the world is energy issue. In order to reduce the usage of fossil fuels, which damage the environment, building must be designed by taking into consideration of energy efficient strategies or existing building must be renovated.

In Turkey primary school buildings have great importance in energy consumption. Reducing this energy consumption supplies beneficial effect in total energy consumption In this project, energy savings of primary school buildings through energy efficient renovation strategies in building envelope are calculated.

With supports of these people this study has been finished.

First of all I would like to thank and express my sincere gratitude to Prof. Dr. A. Zerrin Yılmaz, my supervisor, who supported me every period of my thesis. Her guidance always helps me both in studies and in life.

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ABBREVIATIONS

std. : Student
Op. Spt. A. : Open Sport Area
Serv. : Service
Mult. Purp. C. : Multi Purpose Center
Ass. : Assistant
Cl. : Classroom
Lb. : Labaratory
R. : Room
S. : Space
TEP : Ton Equal Petrol
DDZ : Day-degree Zones
WR : Window Renovation
SD : Shading Devices
IIT : Increasing Insulation Thickness
SP : Summer Period
ORC : Organic Rankine Cycle

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ENERGY SAVINGS OF PRIMARY SCHOOL BUILDINGS IN TURKEY THROUGH ENERGY EFFICIENT RENOVATION STRATEGIES IN BUILDING ENVELOPE

SUMMARY

The aim of this thesis is, determining the total energy savings of school buildings in Turkey, by applying the energy saving results of one school building to the all other school buildings in that climate region when the energy efficient renovation strategies are used. There are some primary school building designs, which are called “type" school design and which are constructed in all climate regions in Turkey. One type primary school project (10025 R-720) whose all drawings have been taken from Turkish Republic the Ministry of Public Work and Settlement are used for calculations in this study. Thermal behaviors are analyzed and evaluated its thermal performance and energy demand of this school project example in Turkey, by using simulation program Thermplan-TRANSIT. Firstly, thermal performance and energy demand are calculated for base case, then some renovation strategies are suggested and then thermal performance and energy demand are calculated for these renovation strategies.

This thesis includes 5 chapters:

The first chapter is Introduction. This chapter emphasizes the young population ratio that are at the primary school age in Turkish population. Then it is explained that the number of primary schools also have an important ratio all over the school buildings and making energy savings in these primary school buildings can be so effectively in total energy consumption of school buildings.

The second chapter is Primary School Education. In this chapter importance of primary school education, requirements of primary school buildings and energy consumptions strategies in design are mentioned.

The third chapter is Energy Consumption in Turkey. In this chapter sectorel dispersion of energy consumption in Turkey and energy consumption ratio of primary schools in total energy consumption are investigated.

The forth chapter is Energy Efficient Design and Parameters. It includes energy efficient design and parameters, suggested renovation strategies.

The fifth chapter, Evaluating the Energy Consumption in Different Climate Regions by Making Some Renovation Strategies, composes the main chapter of the study. First, it defines the climate zones and characteristic cities for this climate zones in Turkey. Then, it defines the case study building. Lastly, after calculating energy demand for winter and summer period total energy demand is evaluated.

The sixth chapter, Determining the Energy Savings. Firstly, numbers of schools for characteristic cities are defined. After determining the total energy savings for one school, total energy savings and costs for all schools in characteristic cities are calculated.

TÜRKİYE'DEKİ İLKÖĞRETİM BİNALARINDA BİNA KABUĞUNDAKİ ENERJİ ETKİN İYİLEŞTİRME YÖNTEMLERİYLE ENERJİ KAZANÇLARI

ÖZET

Bu tezin amacı, enerji etkin iyileştirme yöntemleri kullanıldığında, bir iklim bölgesinde bulunan ilkokul binasındaki enerji kazanımını, o iklim bölgesindeki tüm okullara uygulayarak, okul binalarındaki toplam enerji kazanımını hesaplamaktır. Türkiye'de "tip" proje olarak adlandırılan, değişik iklim bölgelerinde uygulanan ilkokul binaları vardır. Bu çalışmadaki hesaplamalarda tüm çizimleri Türkiye Cumhuriyeti Bayındırlık ve İskân Bakanlığı'ndan alınan tip ilkokul projelerinden birisi (10025 R–720) kullanılmıştır. Thermplan-TRANSIT simulasyon programı kullanılarak, Türkiye'deki bu örnek okul binasının termal davranışları analiz edilmiş, termal performansı ve enerji ihtiyacı hesaplanmıştır. Öncelikle temel durum için ısısal performans ve enerji ihtiyacı hesaplanmış, daha sonra da bina kabuğu için bazı iyileştirme stratejileri önerilmiş ve ısısal performans ve enerji ihtiyaçları bu iyileştirme yöntemleri için hesaplanmıştır.

Bu tez beş bölüm içermektedir:

Birinci bölüm Giriş bölümüdür. Bu bölümde Türkiye nüfusundaki ilkokul çağında bulunan genç nüfus oranı vurgulanmaktadır. Daha sonra ilkokul binalarının tüm okul binaları içinde önemli bir yere sahip olduğu belirtilmiş, bu okullarda yapılacak enerji kazanımlarının toplam enerji tüketimindeki olumlu etkisi vurgulanmıştır.

İkinci bölüm İlköğretim Eğitimi ile ilgili bölümdür. Bu bölümde ilköğretim eğitiminin önemi, ilkokul binalarının gereksinimleri ve enerji tüketiminden bahsedilmiştir.

Üçüncü bölüm Türkiye'deki Enerji Tüketimi'dir. Bu bölümde enerji tüketiminin sektörel dağılımı, okullardaki enerji tüketimi incelenmiştir.

Dördüncü bölüm Enerji Etkin Tasarım ve Parametreleri'dir. Bu bölüm enerji etkin tasarım, parametreleri ve bina kabuğu için önerilen iyileştirme yöntemlerini içermektedir.

Beşinci bölüm Bina Kabuğundaki İyileştirme Yöntemleriyle Değişik İklim Bölgelerindeki Enerji Tüketimini Hesaplamak olup, bu çalışmanın asıl bölümünü oluşturmaktadır. Bu bölüm öncelikle Türkiye'deki iklimsel bölgeleri, özelliklerini ve karakteristik şehirlerini tanımlar. Daha sonra örnek binayı tanımlar. Son olarak da seçilmiş ilkokul tasarımı için temel durumda ve iyileştirme yöntemleri uygulanmış durumda yaz ve kış dönemlerindeki enerji ihtiyacı hesaplanarak, toplam enerji ihtiyacı belirlenir.

Altıncı bölüm Enerji Kazanımlarının Belirlenmesi'dir. İlk olarak karakteristik şehirlerdeki okul sayıları belirlenir. Daha sonra bir okul için belirlenen toplam enerji kazanımı diğer tüm okullara uygulanarak, o karakteristik şehir için toplam enerji kazanımı belirlenir. Son olarak da tüm şehirlerdeki okullarda elde edilen kazanımlar toplanarak Türkiye genelindeki toplam enerji kazanımına genel bir bakış açısı getirilmeye çalışılır.

1. INTRODUCTION

Percentage 75 of Turkish population is occurred of young people at school age. The proportion of children who are attending to primary school is the most in this young population. Like the same way, the proportion of primary school buildings is also the higher in all school buildings. Making renovations in these primary school buildings will reduce the energy demand of the building, as a result, this reduce will cause benefits to the economy.

Increasing prices and realization that fossil-fuel resources are limited encouraged the solar energy work. Use of solar energy for space heating is environmentally sounder than the use of coal. Coal is source of pollution and perhaps on a large scale, a major danger to our climate. One immediate problem with coal (and oil and natural gas) is the called 'acid rain'produced when sulphur dioxide and other contaminants from power stations combine with vapour in the atmosphere to form sulphuric acid. Upon falling to earth as rain, it seeps into the soil, releasing aluminium and manganese, and poisoning trees [1].

In the long term, fossil fuel burning affects the carbon dioxide content of the atmosphere and this is presently a subject of great concern. The danger is that the increasing carbon dioxide content could lead, via the 'greenhouse effect', to retention of heat that would otherwise escape from the lower atmosphere and so warm the earth's surface and perhaps drastically affect climate [1].

Over the past two decades particularly during the "oil crises" of late 1970's and early 1980's the implications of our dependence on fossil fuels have created a marked awareness within the building community of the need to conserve energy in the design of buildings [2].

In the long term, fossil fuel burning affects the carbon dioxide content of the atmosphere and this is presently a subject of great concern. The danger is that the increasing carbon dioxide content could lead, via the "greenhouse effect", to retention of heat that would otherwise escape from the lower atmosphere and so warm the earth's surface and perhaps drastically affect climate [1].

After oil crises, energy efficient building design became more popular because of reducing the fuel oil dependence.

School buildings, especially primary school buildings have an important ratio in residential buildings. For this reason, energy savings are important in school building design. While designing a new building the aim must be to take into consideration of all climatic conditions, site properties and typical building types in that region during design period. Tendency must be to design building systems, which use minimum energy. Firstly, passive systems must be thought and used, and then active systems must be added to get more performance. If only active systems are added to building after construction, without taking any consideration of energy efficient design parameters during the design and construction period, it will not be true assuming that building as a real energy efficient building.

Energy efficient building design means requiring the minimum amount of energy for heating, cooling, equipment and lighting that is required to maintain comfort conditions in building. The energy efficient buildings must adjust their self by utilizing natural resources of lighting, heating, cooling or by avoiding from them if they make no benefit for building environment. These are the renewable energy sources like solar, wind. Furthermore, the mechanical systems in this building have to be controlled being compatible with the passive systems if it is required. An important factor impacting on energy efficiency is the building envelope. This includes all of the building elements between the interior and the exterior of the building such as: walls, windows, doors, roof and foundations. All of these components must work together in order to keep the building warm in the winter and cool in the summer [3].

One of the most important factors for building design is climate. Solutions, which are profited by the possitive effect of climatic datas and protected by the negative effects of climatic datas, must be thought. This approach makes it possible to design physically comfortable spaces [4].

The most important design parameters affecting indoor thermal comfort and energy conservation in building scale are orientation, building form, optical and thermophysical properties of building envelope. All of these parameters are related to each other and the optimum on the values of each other [5]. For existing buildings there is no chance to change energy efficient parameters except building envelope. Some renovations can be made in building envelope and energy demand can be reduced by using these renovation strategies. In cold climates increasing insulation thickness, window renovation, if it is possible, winter garden and trombe wall application, in hot climates window renovation, using shading devices can be given as some types of these renovation strategies. Some other different renovations can also be added.

In Turkey, heating demand for school building is important than cooling demand. Because in Turkish education system, summer holiday period begins at 15 June and finishes at 15 September. On the other hand, from September to April, heating is required in buildings. It is necessary to use renovation sytems, which reduce the heating demand of building.

A space, which does not use active heating system, is a passive heating system as a whole. A space that has an optimal performance as a passive heating system support required optimal indoor climate conditions [6]. Heating economy in building is not only depending on the precautions during system occupation hours, but also it depends on the decisions, which are taken during the building design [7].

The aim of this thesis is calculating the energy savings if energy efficient renovation strategies for one school in one climate region are applied to all of the school buildings in that region. In Turkey there are some primary school building designs which are constructed in all climate regions. These projects are called “type” school designs and some details like insulation thickness can change according to the climate regions. One of this type primary school project (10025 R-720) whose all drawings have been taken from Turkish Republic the Ministry of Public Work and Settlement is used for calculations in this study.

2. PRIMARY SCHOOL EDUCATION

Primary school education is so important in peoples' life. After kinder garden, in primary school a child meets with another new community. In this new community, children take more responsibilities than kinder garden and they begin to understand life.

2.1. Importance of Primary School

Turkish population is occurred mostly young people. An important ratio of this young population is occurred children who are primary school students between the ages of 7–11. It is accepted that primary school education is essential and very important residential service that must be given to the all people who are at the school age and it is an obligation to have a primary school education [8].

Reasons for obligation primary school education are listed:

- To prevent the inequality that is occurred when having education depends on only family choices
- To improve creative and productive features of community, assisting all members of community about usage of citizenship rights and freedom,
- To prevent children from going to work, instead of going to school,
- To provide profitable usage of population in productive areas,
- To eliminate negative effects of low income, that obstructs improvement of skills and abilities by diffusing education.
- To supply equality in education [8].

2.2. Requirements of Primary Schools Buildings

Psychological, social, design, construction and energy requirements can be said as the requirements of school buildings.

2.2.1. Psychological and Social Requirements

- To create an effective and creative education atmosphere this helps for children to explain themselves and to improve their responsibilities,
- To create spaces which make possible students to have a wide world view,
- To prepare programmes that helps children for being individuals who have good qualifications in science, social and cultural fields,
- To get childrens their skills that helps them to adopt the society, culture and nature they belong to,
- To prepare the programs, this integrates the neighborhoods and family to education [9].

2.2.2. Design and Construction Requirements

Determining the demand program according to number of students, determining the relationship between the spaces and determining the construction system and material choice are design and construction requirements.

2.2.2.1. Determining the demand programme according to the number of students

Demand programmes of schools are different according to the number of students.

Table 2.1: Areas of primary school buildings, which has branch I to V [9]

	I Branch	II Branch	III Branch	IV Branch	V Branch
Total Construction Area	2558 m2	3831 m2	4725-6625 m2	5545-7445 m2	6565-8465 m2
Total Functional Area	1535 m2 %60	2299 m2 %60	3975 m2 %60	4467 m2 %60	5079 m2 %60
Total Circulation Area	1023 m2 %40	1532 m2 %40	2650 m2 %40	2978 m2 %40	35386 m2 %40
Total Student Number	260	520	760	1000	1240
Functional Area for per Student	5.9 m2	4.4 m2	5.2 m2	4.5 m2	4.1 m2
Circulation Area for per Student	3.9 m2	2.9 m2	3.5 m2	3.0 m2	2.7 m2
Total Construction Area for per Student	9.8 m2	7.4 m2	8.7 m2	7.4 m2	6.8 m2
Largeness of Required Land	3000-4000 m2	5000-6000 m2	7000-8000 m2	9000-10000 m2	11000-12000 m2
Construction Base Area / Open Area	1/3	1/3	1/3	1/3	1/3
Open Area for per Student	~ 10 m2	~8.0 m2	~8.0 m2	~8.0 m2	~8.0 m2

Table 2.2: Demand programme of primary school buildings which has IV branch [9]

Space name	Number	Person Number	m2	Total m2
A. Kindergarden (40 std)				
Education Area	2	20	80	160
Storage	1	-	20	20
Teachers' Room	1	3	20	16
Usage Room	1	-	8	8
Total				204
B. Primary Schoool (1200 std)				
1. Classrooms				
Constant Classrooms	15	30	52	780
Branch Classrooms				
Turkish	4	30	52	208
Mathematics	3	30	52	156
Science	1	30	52	52
Social Science	2	30	52	104
Foreign Language	2	30	52	104
General Classrooms	4	30	52	208
Social Activity Classrooms	5	5	10	50
2. Laboratories				
Science Labaratory	2	30	72	144
Preperation Room	1	-	16	16
Computer Room	2	60	52	104
Project Room	1	20	48	48
Art Room	1	30	72	72
Keramik room	1	-	8	8
Keramik Oven	1	-	8	8
Music Room	1	30	72	72
Storage	1	-	8	8
Bookcase	1	-	80	80
Group Study Room	4	5	10	40
Storage (General)	1	-	16	16
Total				2533
C. Management				
Manager Room	1	1	16	16
Manager Assistant Room	5	1	12	60
Office	1	4	24	24
Storage /Archieve	1	-	16	16
Teachers' Room				
Sitting Part	1	15	40	40
Branch Teachers' Room				
Meeting Room	1	40	62	62
Study Room	1	16	32	32
D. Common spaces				
Workshop 1	1	30	72	72
Workshop 2	1	30	72	72
Storage	2	-	16	32
Library				
Bookcase	-	-	30	30
Individual Study Area	1	30	72	72
Information Technologies	1	12	35	35
Card Catologue	-	-	8	8
Library Staff	-	-	10	10

Table 2.2: Demand programme of primary school buildings which has IV branch [9] (continued)

Space name	Number	Person Number	m2	Total m2
Copy	1	-	24	24
Emergency Room	2	2	24	48
Guidance				
Guidance Room for Groups	2	12	24	48
Office	2	3	16	32
Total				483
E. Cafe				
Canteen 1	1	60	48	48
Canteen 2	1	150	120	120
Canteen 3	5	-	25	25
Stationery				
Selling Part	1	-	24	24
Storage	1	-	8	8
Total				225
F. Supporting Units				
Retainer Changing Room	2	4	8	16
Cleaning Room	4	-	5	20
Technical Room	1	2	12	12
Storage (General)	3	-	32	96
Heating System Center	1	-	100	100
Total				244
Total (General)				3939
Total Construction Area				6565
G. Sport Center	1	-	640	640
Audience Part	-	400	220	220
Stage	1	-	40	40
Off- Storage	1	-	56	56
Stage Storage	1	-	32	32
Changing Room (Boy)	1	-	48	48
Changing Room (Girl)	1	-	48	48
Teacher Changing Room (Man)	1	-	12	12
Teacher Changing Room (Woman)	1	-	12	12
Storage	1	-	32	12
Total (General)				1140
Circulation Area				760
Total Construction Area				1900
Total General				8465

In Table 2.1 areas of primary school buildings, which has branch I to V can be seen. Demand programme of primary school buildings which has IV branch can be seen in Table 2.2. In Figure 2.1 relationship between the spaces in primary school can be seen. In fact most of school buildings the connection of the spaces like classrooms, management parts, classrooms and multi purpose spaces of school buildings have nearly same connection like this school building have.

2.2.2.2. Determining the relationship between the spaces

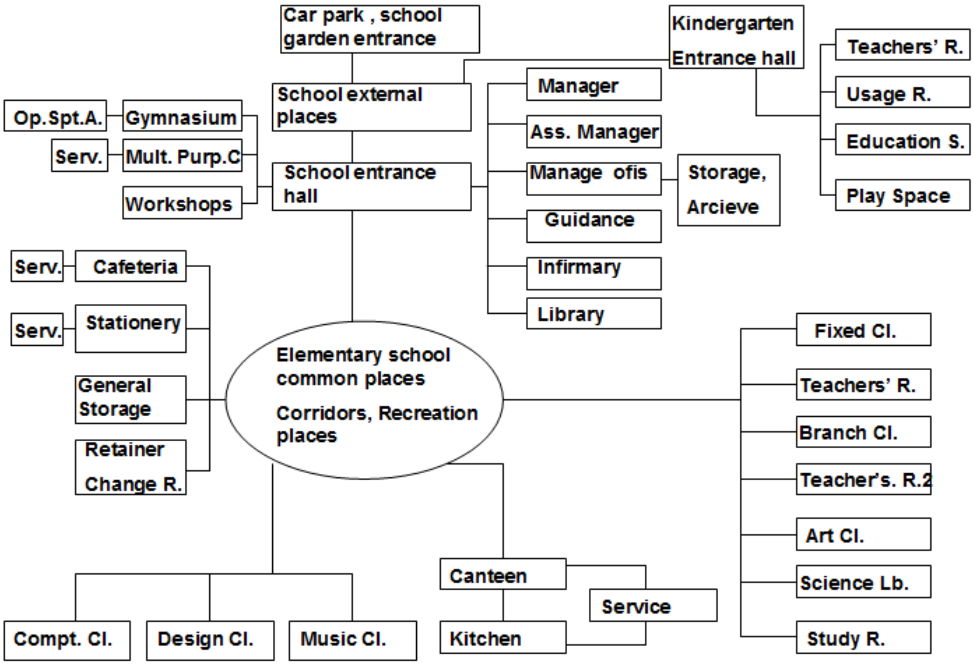

Figure 2.1: Relationship between the spaces in primary school building [9]

2.2.2.3. Determining construction system and material choice

The issues that must be taken into consideration while determining the construction systems and material choices are;

- Suitability of the project for this regional construction system,
- Ability to carry the building loads,
- Suitability of the project to fire protection,
- Getting the material easily in that region,
- Suitability of the building for the climate conditions and durability of the building,
- Suitability of architectural and functional concept [9].

2.2.3. Energy Consumption

Primary schools must be design according to the energy savings conscious; the systems, which reduce the annual energy consumption costs and fuel oil usage, must be improved. It must be taken into consideration alternative solutions with the original designs that determine local climate conditions and passive energy usage besides classical solutions. Especially for Turkey, geothermal, wind and solar energy must be taken into consideration [9].

3. ENERGY CONSUMPTION IN TURKEY

Sectoral distribution of energy consumption in Turkey, consumption of energy sources in buildings, and energy consumption of schools in some cities can be seen in the following tables.

3.1. Sectoral Share of Energy Consumption in Turkey

In Turkey energy consumption sectors are industry, buildings and services, transportation and agriculture. (Table 3.1) Industry has the greatest share. Types of energy sources are fossil fuels and electric; as it is seen in Table 3.2 fossil fuel consumption is nearly % 80 of whole consumption

Table 3.1: Sectoral distribution of energy consumption in Turkey [10]

Sector	Consumption (thousand TEP)	%
Industry	20471	37
Buildings and Services	20015	36.1
Transportation	12000	21.6
Agriculture	2951	5.3

Table 3.2: Consumption of energy sources in buildings [10]

Type of Energy Source	Consumption (thousand TEP)	%
Fosil fuels	15907	79.5
Electric	4108	20.5
TOTAL	20015	100

3.2. Energy Consumptions of School Buildings in Some Cities in Turkey

In Turkey schools are built in different time zones. % 1 of schools are built before the year 1923, % 4.7 are built between the years 1923-1949, % 4.7 are between the years 1950-1959, % 15.3 are built between years 1960-1969, % 14.2 are built the years 1970-1979, %22 are built between the years 1980-1989, %17.7 are built between the years 1990-1994 and % 20.4 are built 1995-1999 [10] .

In Turkey there are four thermal zones according to the insulation application which are called degree-day zones. Some of the cities in these different zones are shown below.

- 1. Degree-Day Zone: Antalya
- 2. Degree-Day Zone: İstanbul, Diyarbakır
- 3. Degree-Day Zone: Ankara
- 4. Degree-Day Zone: Erzurum [11].

In the following tables, numbers of schools, and energy consumptions are shown

Table 3.3: Energy consumption of regions [10]

Region	Number of Buildings	Fuel Consumption kWh / m^2	Electric Consumption kWh / m^2	Total Energy Consumption kWh / m^2
1. Region DDZ	441	154	30	184
2. Region DDZ	4226	193	46	239
3. Region DDZ	2967	236	27	263
4. Region DDZ	2517	262	22	284

Table 3.4: Fuel consumption of school buildings [10]

Fuel Consumption	%
Coal	76.7
Fuel oil	21.4
Natural Gas	1.2
Motorin	0.7
TOTAL	100

As it is seen in Table 3.3 and Table 3.4 energy consumption is high for school buildings. Especially fossil fuel consumption has a great percentage in total energy consumption. For this reason, some renovation strategies must be improved for to reduce the fuel consumption.

4. ENERGY EFFICIENT DESIGN AND PARAMETERS

Wrong shaping on energy preference and consumption effect countries negatively whose economy depends on energy imports and causes decrease of limited resources. Besides using fossil fuel resources like petrol, coal in buildings and industry or using these resources for producing electricity are the causes of this problem. CO2 emission causes greenhouse effect, also causes the change of ecological balance, and causes water, atmosphere and soil pollution [12].

After industry revolution, some mechanical systems are improved to occupy comfort conditions artificially. The systems that are independent from the climate caused widespread design of buildings, which have mechanic cooling and ventilation systems [12].

Le Corbusier's definition is "Building is a machine in which people live". According to this definition, it can be seen technological and engineer solutions dominated in 20th century. Architecture history remember this century as a century that building which imitate machines. The reason for this is after the industry revolution machines became a symbol of humans' domination of nature. Thus, buildings are adorned typical properties of the production of montage like machines. They ignore culture and climate, for this reason they became more similar each passing day. Although there are regional, cultural and climatic differences, office buildings in Singapore and New York are the same. As they are not shaped according to original conditions, all of them are related to the same artificial comfort condition system, are using energy resources and polluting environments [12].

Before the industry revolution , architects took living organism which found convenient solutions to the environment and climate conditions as example and building are evolutioned amicable to nature. It must be known that buildings can be respectful to the nature like living organism that live in polars, deserts even in oceans 8000 m dept, and have different features with their adaptation [12].

Most important thing is to design comfort buildings, which are become integrated to nature, and gives no harm to nature with its energy using and wastes [12].

When it is thought about flowers with various shape, color and dimension they can give required reaction to light, temperature and solar energy, they should take root, which is the only similarity with buildings. These flowers supply their energy from sun, they use only the possibilities of region where they take root and they do not want much more than they require or they do not give harm to the environment. In addition, they look like a good ecosystem that supplies living areas to insects and microorganisms [12].

First aim of the building solutions in 21st century is "decreasing the negative effects of buildings to the environment at least level". Ecological ethic, which makes technology harmonious to nature, must take place of the opinion that technology means controlling the nature and means power and wealth. Ecotechnologies, which can make possible usage of renewable sources like solar energy, wind energy, must be improved [12].

4.1. Energy Efficient Design and Renovation Strategies

An architect has to take in consideration of an energy efficient design from beginning of design to the end of construction of building. It is better to try to design a building according to the energy efficient design parameters, but sometimes for an existing building, this is not possible. In this situation, some renovations can be done in building envelope, which helps to have comfortable atmosphere [3, 13, 14].

4.1.1. Energy Efficient Design Parameter

Energy efficient design parameters are location of building, site of building, orientation of building, shape of building and building envelope.

4.1.1.1. Location of Building

Location of the building determine the micro-climate conditions which has very important role in building energy efficiency, as it is important for learning, climatic values like sun radiation, air temperature, air circulation, humidity which effect energy costs [3, 13, 14].

4.1.1.2. Site of Building

Site of building and distance between other buildings are one of the most important design parameters, which effect sun radiation amount and air circulation velocity around the buildings. For this reason site of the building in area should be determined to benefit and defend from the renewable energy resources like sun and wind [3, 13, 14].

4.1.1.3. Orientation of Building

Orientation of building and distance between the buildings are important parameters, which affect the ratio of the solar radiation gain of building sides, consequently total solar radiation gain of building. In addition, side of buildings effect wind amount, consequently, effect natural ventilation possibility and heat loss amount by convection and air lack. For this reason according to the necessities of that region, buildings must be oriented for avoid of or benefit from the sun and wind according to the conditions. [3, 13, 14]

4.1.1.4. Shape of Building

Shape of building is important in areas that have different climate conditions. In cold climate regions compact forms should be used which minimize the heat loss part. In hot-dry climate regions compact forms and courtyards should be used which minimize heat gain and helps to provide shaded and cool living spaces. In hot-humid climate region long and thin forms whose long side oriented to the direction of prevailing wind makes possible maximum cross ventilation. In mild climates, compact forms, which are flexible more than the forms used in cold climate regions, should be used [3, 13, 14].

4.1.1.5. Building Envelope and Properties of Building Envelope

The skin of building performs the role of a filter between indoor and outdoor conditions, to control the intake of air, heat, cold and light [15]. According to the climate conditions and heat amount, building envelope, which is composed of opaque and transparent components, has an important effect on interior air temperature that is related to interior surface temperature. Building envelope has physical and optical properties related to heat transfer [3, 13, 14].

Building envelope, which is composed of opaque and transparent elements, has an important role of interior air temperature, related to the interior surface temperature, climate conditions and the heating quantity, which transfer its inside. It has thermal and optical properties [3, 13, 14] .

Thermal Properties of Building Envelope

Thermal properties of building envelope are heat coefficient factor, decrement factor and time lag.

Heat Coefficient Factor for Opaque and Transparent Component (U, W/m2K)

When the temperature difference between the two parts of the building envelope, which is occurred one or more layers is 1K, it is the amount of heat transferred vertical direction in unit area of component.

Decrement Factor (j)

$$\frac{\text{amplitude of temperature difference of interior surface}}{\text{amplitude of temperature difference of outside surface}}$$

Time Lag (f, h)

Time lag is the time difference between the time period at which exterior surface has maximum temperature and interior surface has maximum temperature. [3, 13, 14]

Optical Properties

Optical proporties of building envelope are:

- Transparency (t) for Transparent Components
- Absorbity (a) for Transparent + Opaque Components
- Reflectivity (r) for Transparent + Opaque Components.

α = Absorbity coefficient of component

τ = Transparency coefficient of component (not used for opaque components)

r = Reflectivity coefficient of component [3, 13, 14]

Sum of transparency , absorbity and reflectivity must be equal to 1.

4.1.2. Energy Efficient Renovation Strategies

Besides aesthetic appearance and function, a building should supply ideal comfort conditions. Sometimes a designer cannot have an interference chance to a design from the beginning. In this situation, renovation strategies that can be done in building envelope, which can supply ideal, comfort conditions and help energy savings.

Some renovation strategies in building envelope;

- Increasing insulation thickness,
- Window Renovation,
- Using shading devices.

Increasing Insulation Thickness: Increasing insulation thickness is affective on reducing heating demand of building in cold climate regions. It reduces the heat transfer from one side to another, helps to using less fossil fuel. It has also negative effect in cooling system as increasing the cooling demand in summer, because increasing insulation thickness obstructs night cooling. But in cold climate regions insulation is an important issue, because when we look total energy demand, the importance of heating energy demand is more than cooling energy demand.

Window Renovation: Windows are one of the most significant elements in the design of any building. Whether present as relatively small punched openings in the facade or as a completely glazed curtain wall; windows are usually a dominant feature of a building's appearance. In addition to having, a dominant influence on a building's appearance and interior environment windows can be one of the most important components influencing its energy use, peak electricity demand, and environmental consequences. Heat gain and heat loss through windows can represent a significant portion of a building's heating and cooling load. By providing natural lights, windows can reduce electric lighting loads, as long as effective dimming controls, for light fixtures are employed. Proper window selection and design can also cut peak electricity heating and cooling load, thereby avoiding costly peak demand charges and easing the need for new power plants. In addition, high performance windows influence mechanical systems, not only contributing to reduced operation expense but also to potential equipment downsizing, saving capital costs [16].

Most window and facade assemblies consist of glazing and frame components. Glazing may be a single pane of glass (or plastic) or multiple panes with air spaces in between. These multiple layer units, referred to as insulating glazing units, include spacers around the edge and sometimes low-conductance gases in the spaces between glazing [16].

For windows, a principle energy concern is their ability to control heat loss. Heat flows from warmer to cooler bodies, thus from the inside face of a window to the outside in winter, reversing direction in summer. Overall heat from the warmer to cooler side of a window unit is a complex interaction of all three basic heat transfer mechanisms- conduction, convection, and long-wave radiation. A window assembly's capacity to resist this heat transfer is referred to as its *insulating value* [16]. Heat loss of a building is directly affected by increasing the U-value of building envelope components, especially windows.

Windows and facades are at the cutting edge of new technologies in buildings. With their importance to both the building appearance and interior environment, windows and facades are likely to play a central role in defining future architectural design. Even the best windows used routinely today still impose energy and environmental impacts of buildings. Emerging and future technologies could reduce energy impacts to "zero" and ultimately provide energy benefits to buildings in the form of daylight and passive solar gains [16].

Shading Devices: Especially in the case of direct solar gain to occupied spaces, it may be necessary, to keep out the sun on occasions [1]. The most efficient way of protecting a building is to shade its windows and other apertures from unwanted direct sunlight. In designing a shading system, the aim should be to minimize the unwanted solar gains but not to darken living space and force to occupants to use artificial lighting [17].

Using active systems in buildings correctly and efficiently has also an effect on energy savings.

In this study, increasing insulation thickness, window renovation and shading devices renovation strategies are used and comparison made with these renovations

strategies and base case. Besides these renovation strategies other strategies like trombe wall, double facade, and photovoltaic panels can also be used.

5. EVALUATING THE ENERGY CONSUMPTION IN DIFFERENT CLIMATE REGIONS BY MAKING SOME RENOVATION STRATEGIES

5.1. Climate Zones in Turkey

According to a research that is made for to classify climate regions in Turkey through the climatic datas which are taken from the 35 different center, Turkey has been separated 7 different climate regions by Ümran Emin Çölaşan. In the following studies made by Lütfi Zeren, it is assumed that there are five climate zones in Turkey. These are mild-humid climate zone, hot-humid climate zone, hot-dry climate zone, mild-dry climate zone and cold climate zone [18].

5.1.1. Mild-Humid Climate Zone (İstanbul)

This climate is effective in Marmara region and Black Sea region. İstanbul is the characteristic city for this climate zone.

Evaluations are made according to the climate data between the time zone 1998 January- 2008 December for İstanbul by using the "climate robot" application in internet. According to this evaluations maximum average temperature is 18.8 ˚C, minimum average temperature is 12.2 ˚C, average of daily sunny hours is 6.3 hours prevailing wind direction is north and northeast [19].

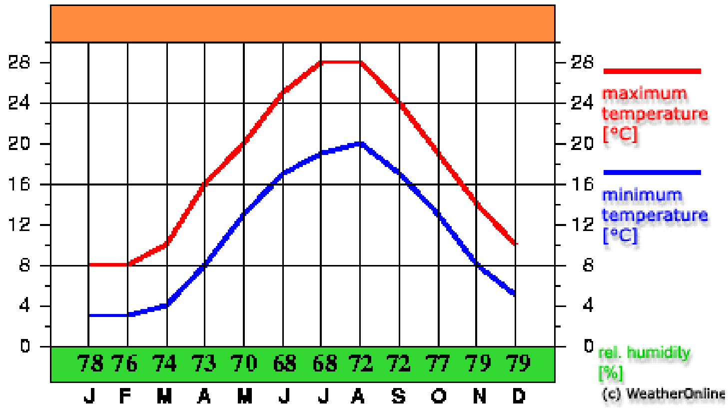

Figure 5.1: Data of annually max/min temperature and relative humidity (İstanbul)[19]

5.1.2. Cold Climate Zone (Erzurum)

This climate zone is effective in East Anatolia region. Erzurum is the characteristic city for this climate zone.

Evaluations are made according to the climate data between the time zone 1998 January- 2008 December for Erzurum by using the "climate robot" application in internet. According to these evaluations, maximum average temperature is 12.6 ˚C, minimum average temperature is -2.1˚C, average of daily sunny hours is 6.6 hours and prevailing wind direction is east and west [19].

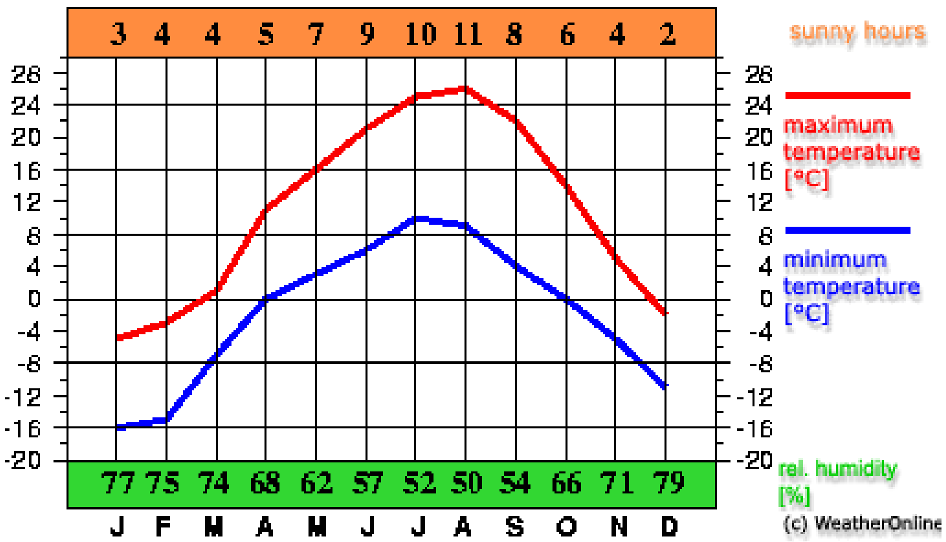

Figure 5.2: Data of annually max/min temperature, relative humidity and sunny hours in (Erzurum) [19]

5.1.3. Mild-Dry Climate Zone (Ankara)

This climate region is effective in Centre Anatolia region. Ankara is the characteristic city for this climate zone.

Evaluations are made according to the climate data between the time zone 1998 January- 2008 December for Ankara by using the "climate robot" application in internet. According to these evaluations, maximum average temperature is 17.4 ˚C, minimum average temperature is 4.0 ˚C, average of daily sunny hours is 7.0 hours and prevailing wind direction is north and northeast [19].

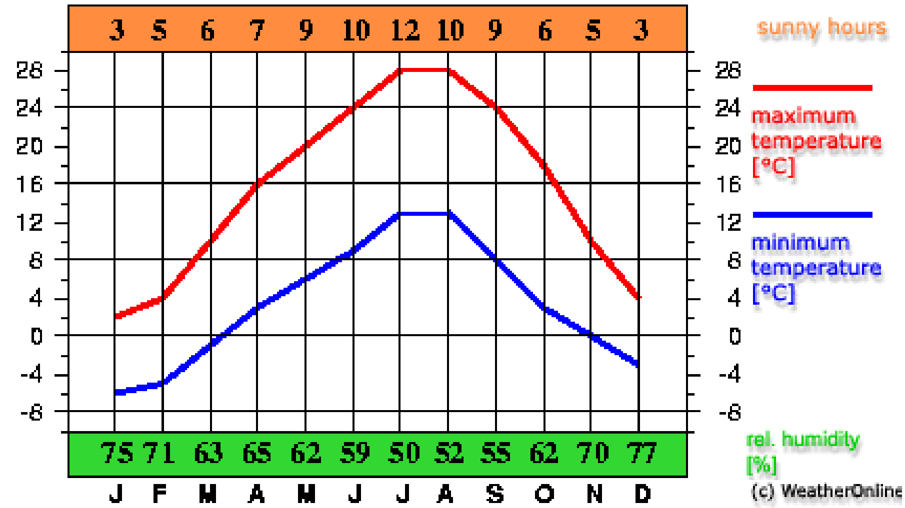

Figure 5.3: Data of annually max/min temperature, relative humidity and sunny hours in (Ankara) [19]

5.1.4. Hot-Humid Climate Zone (Antalya)

This climate zone is effective in Aegean region and Mediterranean Sea region. Antalya is the characteristic city for this zone.

Evaluations are made according to the climate data between the time zone 1998 January- 2008 December for Antalya by using the "climate robot" application in internet. According to these evaluations, maximum average temperature is 25.0 ˚C, minimum average temperature is 14.3˚C, and prevailing wind direction is north and north-west [15].

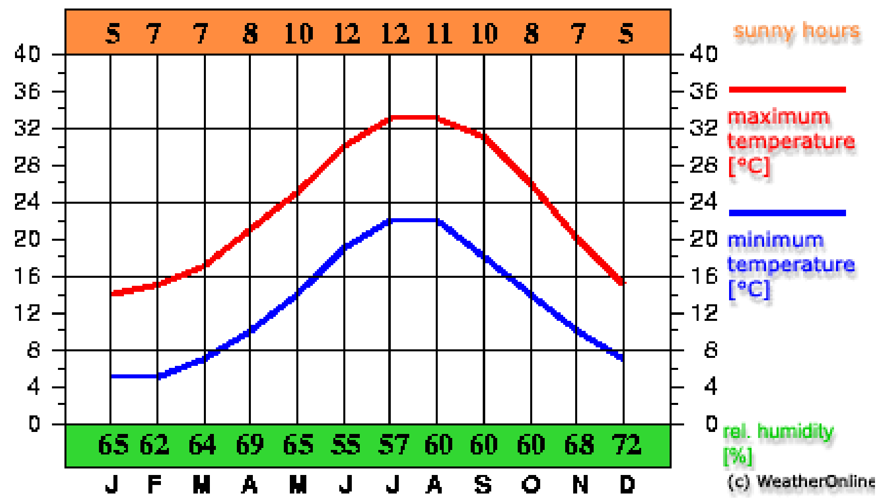

Figure 5.4: Data of annually max/min temperature, relative humidity and sunny hours in (Antalya) [19]

5.1.5. Hot-Dry Climate Zone (Diyarbakır)

This climate zone is effective in South East Anatolia region. Diyarbakır is the characteristic city for this climate zone.

Evaluations are made according to the climate data between the time zone 1998 January- 2008 December for Diyarbakır by using the "climate robot" application in internet. According to these evaluations, maximum average temperature is 23.0 ˚C, minimum average temperature is 8.7 ˚C, average of daily sunny hours is 7.7 hours and prevailing wind direction is north-west and north [19].

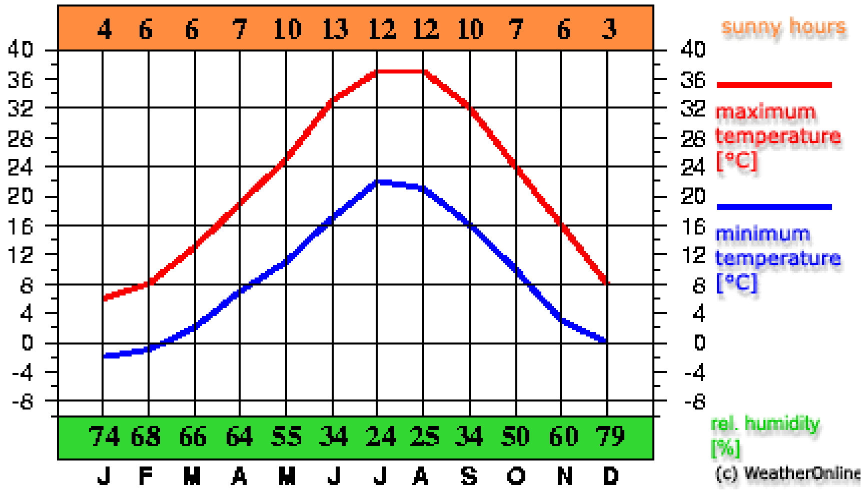

Figure 5.5: Data of annually max/min temperature, relative humidity and sunny hours in (Diyarbakır) [19]

5.2. Definition of Type Primary School Building

In Turkey there are some primary school building designs which are constructed in all climate regions. These projects are called "type" school designs and some details like insulation thickness can change according to the climate regions. One of these type primary school projects whose all drawings have been taken from Turkish Republic the Ministry of Public Work and Settlement has been used for calculations in this study. Type primary school project numbered 10025 R-720 is constructed in all different climate zones in Turkey. This project is occurred kinder garden and primary school, which are adjacent to each other. Primary school part is five floored with basement; kinder garden part is 3 floored with basement. Form of building is rectangle and the classrooms are oriented to the south and north sides. Plan, section and elevation are shown in following figures.

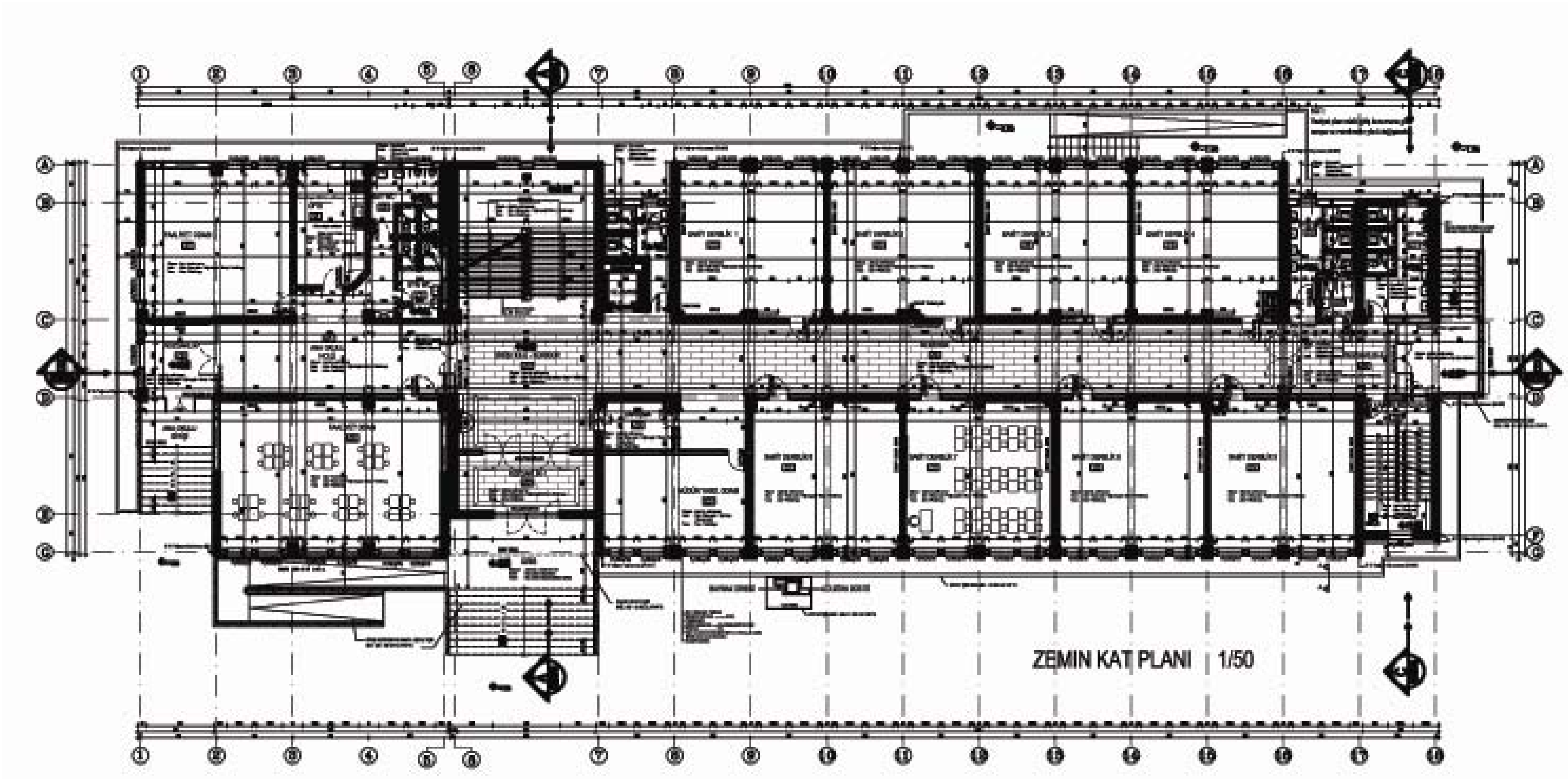

Figure 5.6: Plan of primary school building (10025 R-720)

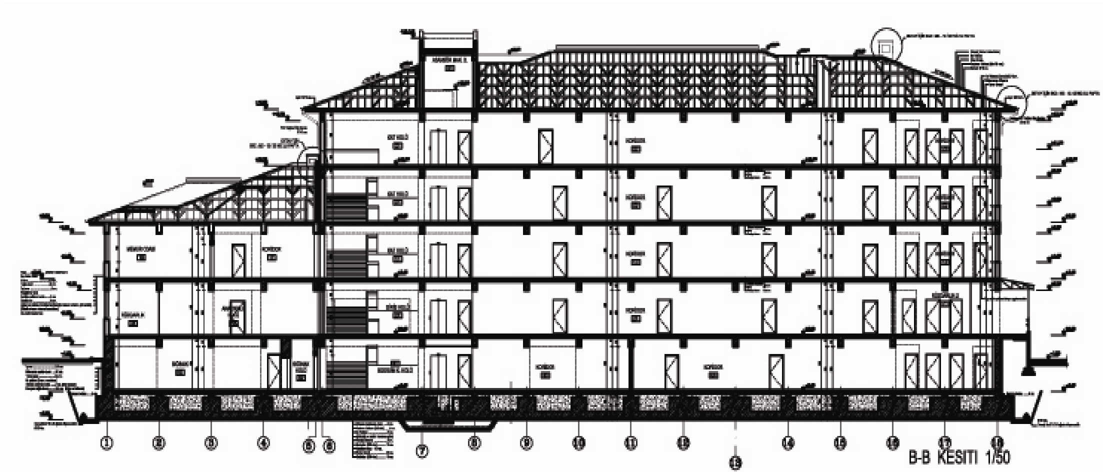

Figure 5.7: Long section of type primary school building (10025 R-720)

Figure 5.8: South elevation of type primary school building (10025 R-720)

5.3. Definition of Simulation (Boundary Conditions)

Thermplan-TRANSIT is used in these simulations. Thermplan-TRANSIT is a multizone building simulation program for calculating the heating and cooling energy demand as well as the zone air temperatures. In addition to the necessity of inputs for building geometry and wall constructions, the environmental conditions (outside temperature and solar radiation) must be given as hourly values.

Firstly building is devided into six zones. Zone 5 and Zone 6 are representing the roof of primary school and kinder garden parts and in these zones it is assumed that heating and cooling system are not working. Zone 1, Zone 3, Zone 4 and Zone 5 (roof) are the zones of primary school part. Zone 2 and Zone 6 (roof) are the zones of kinder garden part. Zones, volumes and areas are seen in the following figure and tables.

In Figure 5.9 zones of primary school are seen. Zone 1, Zone 3 and Zone 4 is primary school part. Zone 2 is kinder garden part. In Table 5.1 volumes and areas of zones of primary school building are seen.

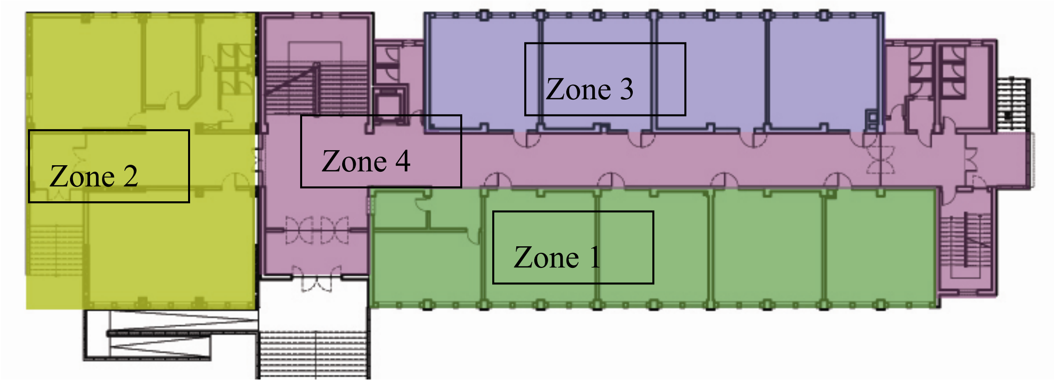

Figure 5.9: Zones of primary school

Table 5.1: Volumes and areas of zones of primary school

	Zone 1 South	Zone 2 West	Zone 3 North	Zone 4 Corridor	Zone 5 Roof 1	Zone 6 Roof 2
Volume (m3)	3930	1755	3154	4848	361	127
Exterior Wall Area (m2)	380	274	308	636	1064	547
Window Area (m2)	176	56	137	31	-	-
Interior Wall Area (m2)	2971	1585	2349	2808	-	-
Adjacent Wall Area (m2)	994	382	728	1690	865	254
Total Area (m2)	4521	2297	3522	5165	1929	802

All of the components of wall, window and adjacent walls of different zones are same. Materials and features are seen in the following tables. Physical properties of windows are seen in Table 5.2.

Table 5.2: Physical proporties of windows

Windows					
	Area(m2)	Heat Transfer Coefficient (w/m2K)	Transmisivity %	Reflectivity %	Absorbity %
South	206.16	2.83	0.590	0.202	0.116
East	12.84				
North	169.48				
West	12.84				

The construction system of building is a concrete system. Physical properties of exterior walls are seen in Table 5.3, physical properties of adjacent walls are seen in Table 5.4 and physical properties of ceiling are seen in Table 5.5.

Table 5.3: Physical proporties of exterior walls

Exterior Wall			
	Thickness (m)	Conductivity (W/mK)	Density (kg/m3)
Interior Plaster	0.03	1.2	1800
Brick Wall	0.29	0.5	1200
Outside Plaster	0.02	1.2	1800
Insulation	0.05	0.04	25
Plaster	0.004	1.2	1800
Covering	0.002	0.55	1600
U-value	0.571 W/m2K		

Table 5.4: Physical proporties of adjacent walls

Adjacent Walls			
	Thickness (m)	Conductivity (W/mK)	Density (kg/m3)
Plaster	0.03	1.2	1800
Brick Wall	0.19	0.27	550
Plaster	0.03	1.2	1800
U -value	0.704		

Table 5.5: Physical proporties of ceiling

Floor			
	Thickness (m)	Conductivity (W/mK)	Density (kg/m3)
Plaster	0.06	1.2	1800
Concrete Slab	0.15	2.1	2400
Insulation	0.1	0.045	300
U -value	0.335		

U- Values of building are determined according to the thermal insulation regulation for degree-day zones in Turkey as it is seen in the Table 5.6. The basement floor of building is defined with a boundary condition that is accepted 20 ˚C during the occupied period and 15 ˚C during the unoccupied period in winter period. In summer period, it is assumed 26 ˚C during occupied period and 30˚C during unoccupied period. Heating and cooling demand are calculated except basement floor. All window types are assumed that they have a U-value 2.83 W/m2K for base case.

Renovation strategies are recommended for opaque and transparent elements of exterior walls.

Table 5.6: U-values of building envelope according to the degree-day zones

Degree-Day Zones	U_exterior (W/m2K)	U_ceiling (W/m2K)	U_ground (W/m2K)	U_window (W/m2K)
1. DDZ	0.80	0.50	0.80	2.80
2. DDZ	0.60	0.40	0.60	2.60
3. DDZ	0.50	0.30	0.45	2.60
4. DDZ	0.40	0.25	0.40	2.40

Occupancy Time: Occupancy time for primary schools in Turkey is between September and June. Fall semester begins 15 September, finishes 31 January. Spring semester begins 15 February and finishes 15 June. First two weeks of February are midyear holiday. Summer holiday begins from 15 June and ends 15 September. In this study occupation time is taken 1-31 January, which is the coldest time for winter period, and 15 May – 15 June which is the hottest time period for summer period.

Internal Gains: It is accepted that internal gains occur during the occupancy hours. For non-occupied hours, gain from persons and computers are zero. It is assumed that the internal gains are chosen from the Thermplan-TRANSIT list as 120W/person described as “very light work”. For the computers it is also chosen from the Thermplan-TRANSIT as 230W PC with color monitor, per monitor. It is also assumed that all these internal gains are transferred by %50 convection and % 50 radiation.

Ventilation: The fresh air is supplied with natural ventilation. After every lesson, in break times fresh air is supplied by natural ventilation in classrooms. For Ankara, Antalya and Diyarbakır, temperatures of zones are higher in winter period, especially n Zone 1, for this reason mechanical ventilation is used, in real conditions building has not mechanical ventilation. The air is supplied with an air change rate 0.95 1/h.

Heating System: It is assumed that heating system is used in the period September – May. Coldest month in this period is January. For this reason, simulations are made in January. It is assumed that comfort temperature is 20 ˚C and it is working 5 days in one week, from the hour 7.00 to 17.00. It is assumed that space temperature is 15 ˚C in the rest hours of day and holidays.

Cooling Systems: It is assumed that cooling system is working in May and June, which are the hottest months in school period. 15 May- 15 June period is taken for calculations. It is assumed that comfort temperature is 26 ˚C and it is working 5 days of week, from the hour 7.00 until 17.00. It is assumed that space temperature is 30 ˚C in the rest hours of day and holidays.

5.4. Renovation Strategies in Building Envelope of Primary School

There are five different climate conditions in Turkey. Primary school building example, which is investigated in this study, is built every climate conditions in Turkey. Insulation thickness and properties, window type and shading devices are the most important issues in construction. In this study mild-humid climate (İstanbul), cold climate (Erzurum), mild-dry climate (Ankara), hot-humid climate (Antalya) and hot-dry climate (Diyarbakır) conditions are studied. In İstanbul, heating and cooling are investigated and total energy demand of base case compared with window renovation and with shading devices strategy. In Erzurum, in cold climate, most important issue is heating energy demand, for this reason, increasing insulation thickness strategy and window renovation strategy are examined. After calculations, base case situation is compared with renovation strategies. In Ankara hot-dry climate, window renovation, increasing insulation thickness strategy and shading devices are examined. After calculations base case situation is compared with renovation strategies. In Antalya, in hot-humid climate, window renovation and shading devices are examined and base case is compared with renovation strategies. In Diyarbakır, in hot-dry climate, window renovation and shading devices are examined and base case is compared with the renovation strategies.

5.4.1. Mild-Humid Climate Zone Renovations (İstanbul)

Mild-humid climate condition is effective in İstanbul. Heating and cooling energy demand is investigated in this study. For winter period, results in January are taken and for summer period results for 15 May-15 June period are taken. Effects of window renovation in heating demand and window renovation, shading devices and combined strategy in cooling demand and annually energy demand are investigated.

5.4.1.1. Window Renovation

In existing project in all windows, window type, which has a U-value 2.83, is used. Optical properties of window are seen in Figure 5.10.

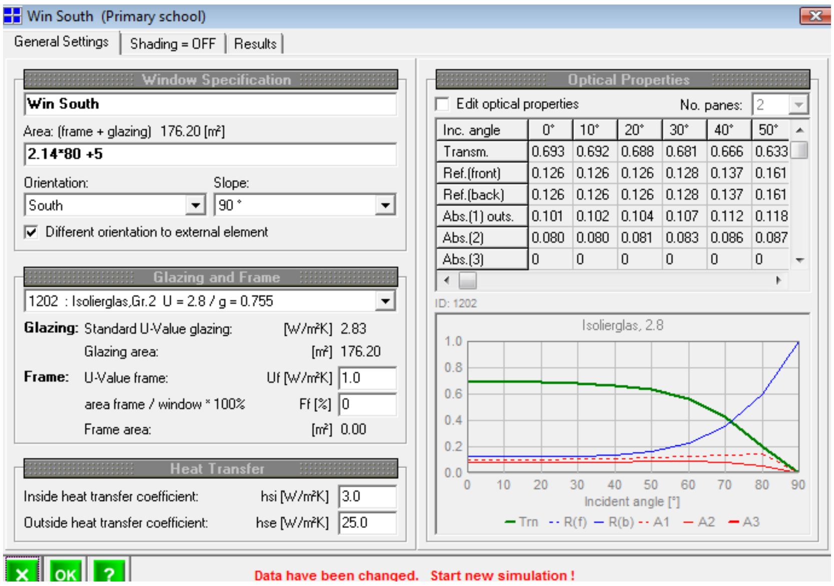

Figure 5.10: Window type for base case

In suggested application in all windows, window type, which has a U-value 1.24, is used. Optical properties of window are seen in Figure 5.11.

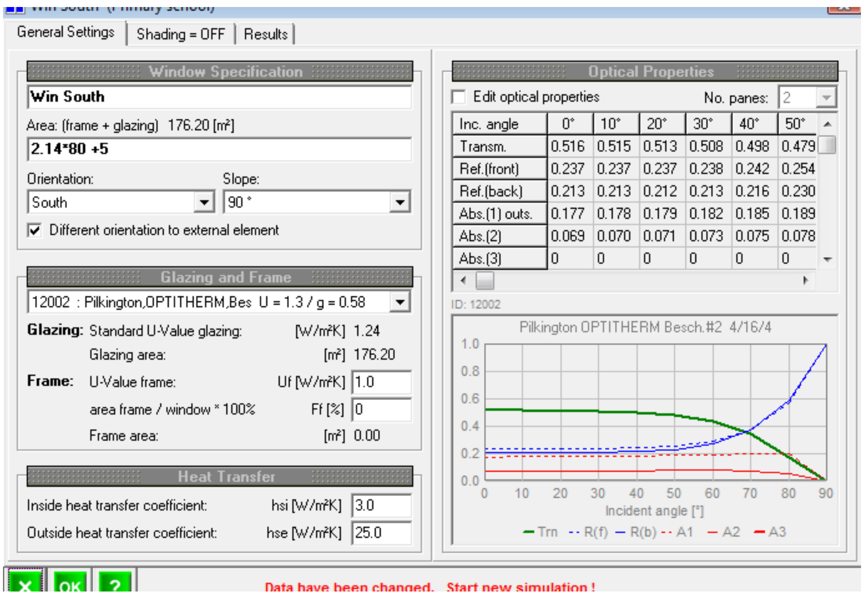

Figure 5.11: Window type for window renovation strategy

5.4.1.2. Shading Devices

The requirements of solar control should be rephrased so as to have the sun strike, the walls and allow the desirable heat energy into the building at all times when the weather is cool; conversely, let us place the building proper in shade at all times when it is hot. On this principle, a balanced solar heat control can be achieved. For this, the first requirement is to clarify what constitutes "cool" and conversely, what can be called "hot". The yardstick to these relative measures is our senses, or rather our physiological reactions [20].

In existing building, shading devices are not used. In suggestion application, shading devices are adjustable and used only in cooling season. Occupancy hours are Monday to Friday, from 12.00 -16.00 pm. In heating period, it is assumed that the shading devices are not working. Shading devices does not transfer sun light. In schools especially for classrooms, light is so important for comfort conditions, for these reasons, shading factor is taken 0.2. not to obstacle sun light for classrooms. Shading device properties and application are shown in Figure 5.12.

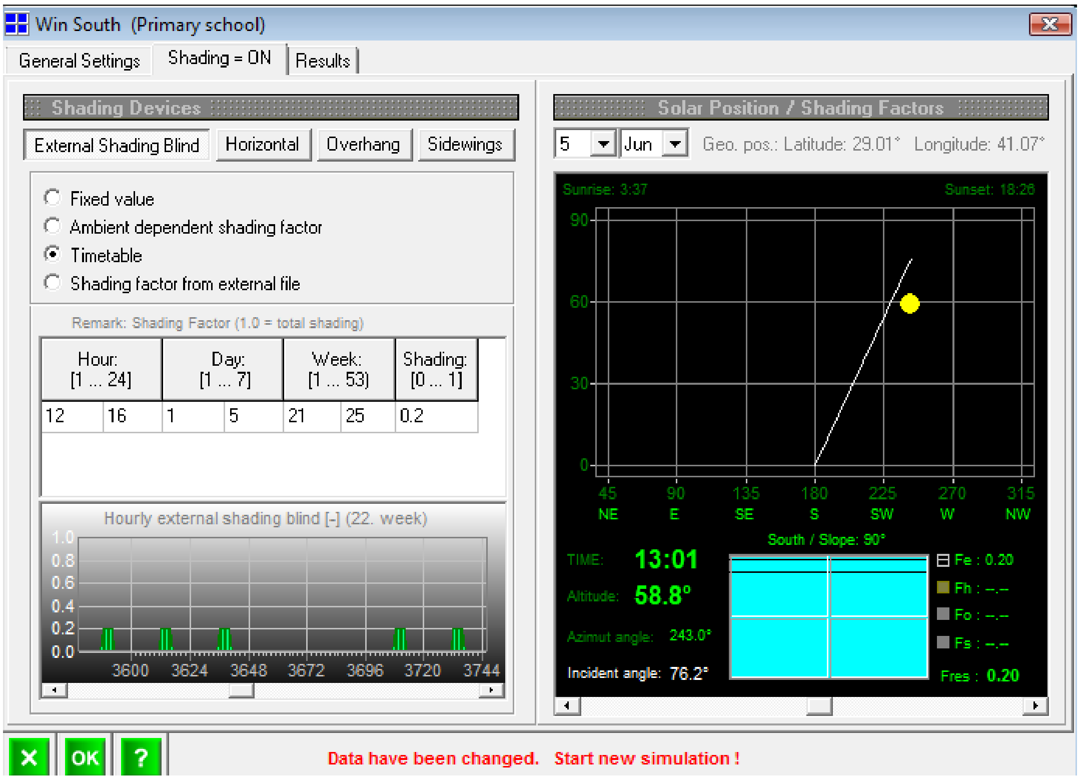

Figure 5.12: Properties of shading devices

5.4.1.3. Winter Period (January) Calculations and Results

Temperatures of zones for base case and window renovation strategies are calculated in this part. (Figure 5.13, Figure 5.14) Heating energy demand for each zones and total energy demand for building are calculated. In this calculation it is assumed that comfort temperature is 20˚C and heating system is working 5 days in one week, from the hour 7.00 to 17.00. It is assumed that space temperature is 15˚C in the rest hours of day and holidays. It is assumed that natural ventilation is used and every break time classrooms are ventilated by opening windows.

Base Case

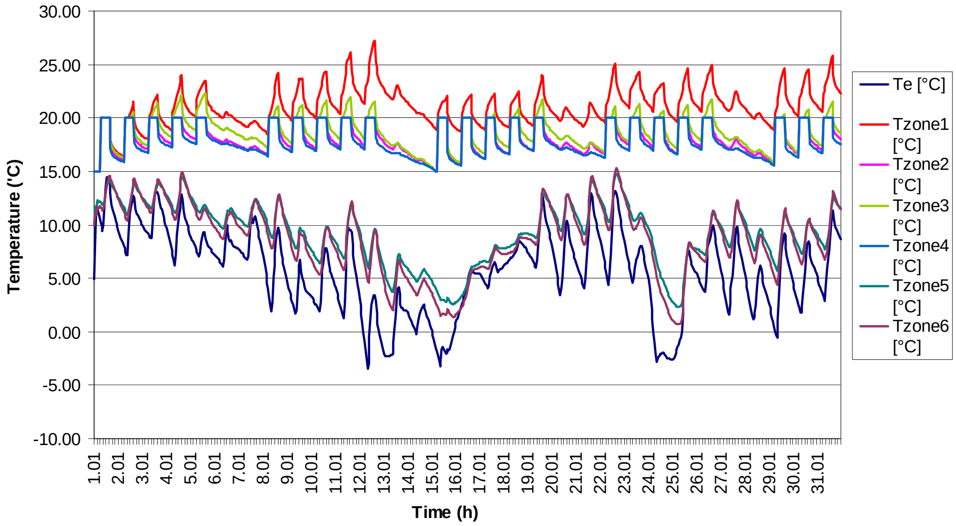

Figure 5.13: Temperatures of zones for base case in January (İstanbul)

Window Renovation

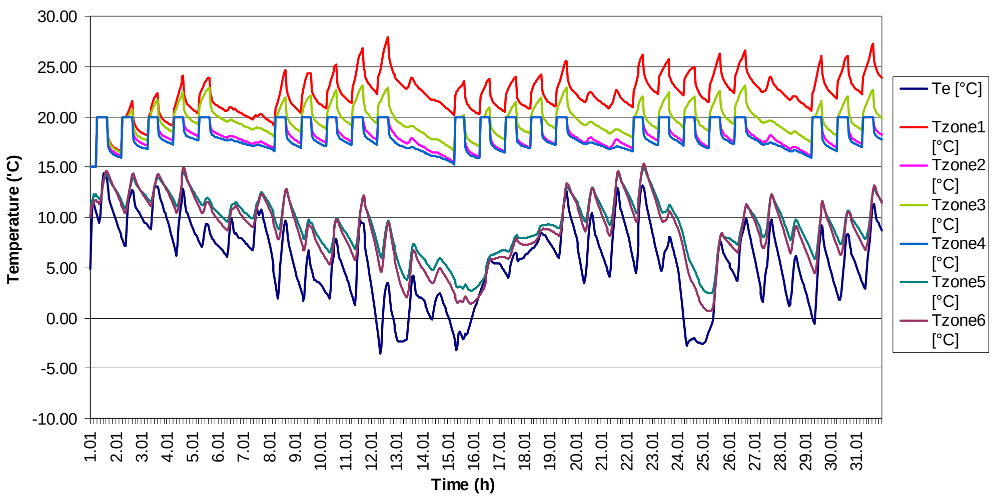

Figure 5.14: Temperatures of zones with window renovation in January (İstanbul)

Table 5.7: Average temperatures of zones for base case and window renovation strategy in January (İstanbul)

Case Type	January	T_amb	Z1	Z2	Z3	Z4	Z5	Z6
Base Case	Average (˚C)	5.69	21.08	18.12	18.67	17.90	9.21	8.65
Window Renovation	Average (˚C)		22.22	18.29	19.65	18.03	9.29	8.67

Zone temperatures for base case and window renovation strategy are seen in Table 5.7. Temperatures of Zone1 (South) is maximum and temperatures for zone 4 is minimum as we compared the heated zones. In zone 1 internal gains are more than the others zones that are why the temperatures are the highest besides being south side. Although zone 3 is located in north side, temperatures are high which has also high internal gains. When it is compared, the temperatures of zones for base case and the situation with window renovation, temperatures of zones for window renovation situation is higher than base case zone temperatures. U-value of windows for window renovation situation is lower than base case, which reduces the heat loss of building.

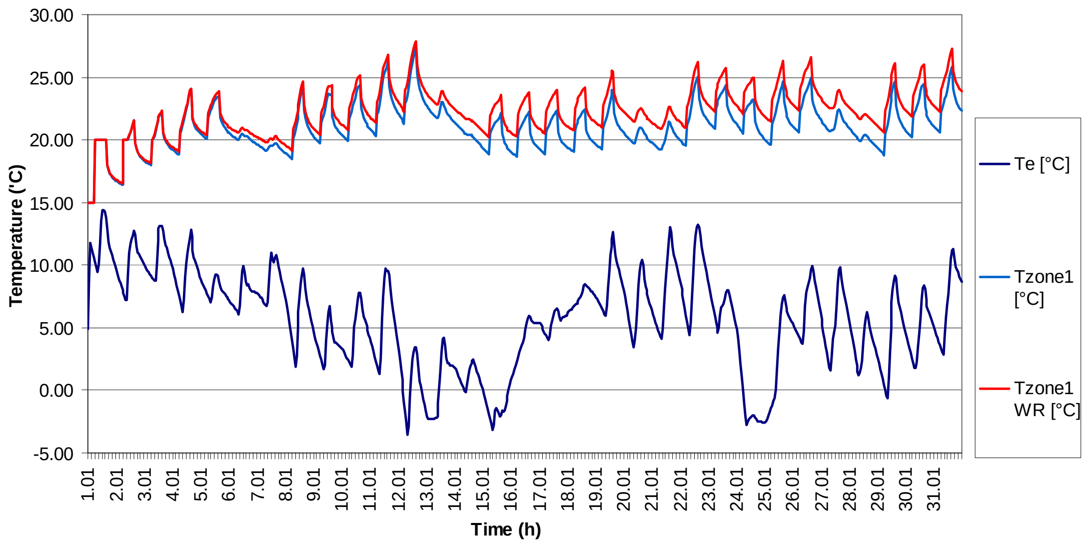

Figure 5.15: Temperatures of zone1 for base case and window renovation strategy in January (İstanbul)

After temperature calculations, it can be seen that temperatures of zone 1 with window renovation are mostly higher than base case. Temperature difference in most parts of calculations is nearly 2 ˚C (Figure 5.15.) However, avarage temperature differences are not so much as it is seen in Table 5.7.

Table 5.8: Energy demand of zones for base case and window renovation strategy in January (İstanbul)

Thermal Zones	Case Type	Heating Energy (kWh)	Heating Load (kWh/m2)
Zone 1	Base case	296.6	0.06
	Window renovation	277.9	0.06
Zone 2	Base case	2989.7	1.30
	Window renovation	2648.4	1.15
Zone 3	Base case	967.4	0.27
	Window renovation	352.7	0.10
Zone 4	Base case	10384.8	2.01
	Window renovation	9755.5	1.88

Heating energy results for each zone are seen in Table 5.8. Maximum heating load is for zone 4, which is the zone that is occurred circulation areas, and it is assumed that it has no internal gain. Zone 1 needs minimum heating energy. It has maximum internal gain and south oriented. Maximum energy savings is in Zone 3, which is oriented at north side. Using low U-values for windows reduces heat loss. Reducing U-values of windows, has much more positive effect in Zone 3 whose energy demand is % 63 less than the base case.

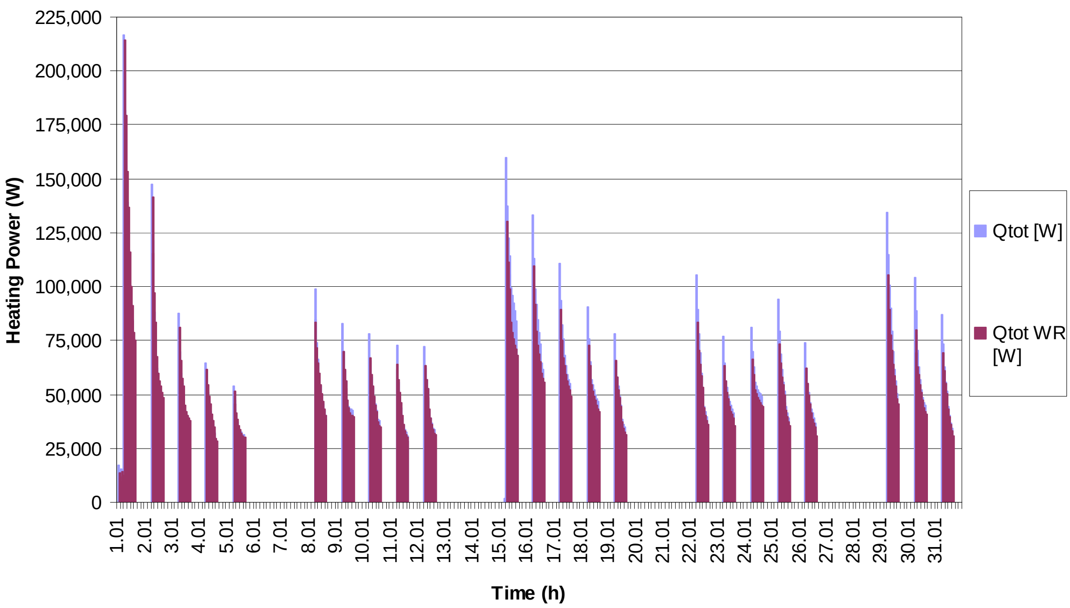

Figure 5.16: Hourly heating power for base case and window renovation situation in January (İstanbul)

Table 5.9: Total heating demand for base case and window renovation strategy in January (İstanbul)

	Base Case	With Window Renovation
Heating Energy (kWh)	14638.5	13034.5
Heating Load (kWh/m2)	0.94	0.84

In winter period, in January heating demand for base case and window renovation situation are seen in Table 5.9 and hourly heating demand is seen in Figure 5.16. Energy savings of building for total heating energy for assumed heating period is 1604 kWh, which can be seeen in Figure 5.17. Energy savings for heating load for assumed heating period is 0.10 kWh / m2.

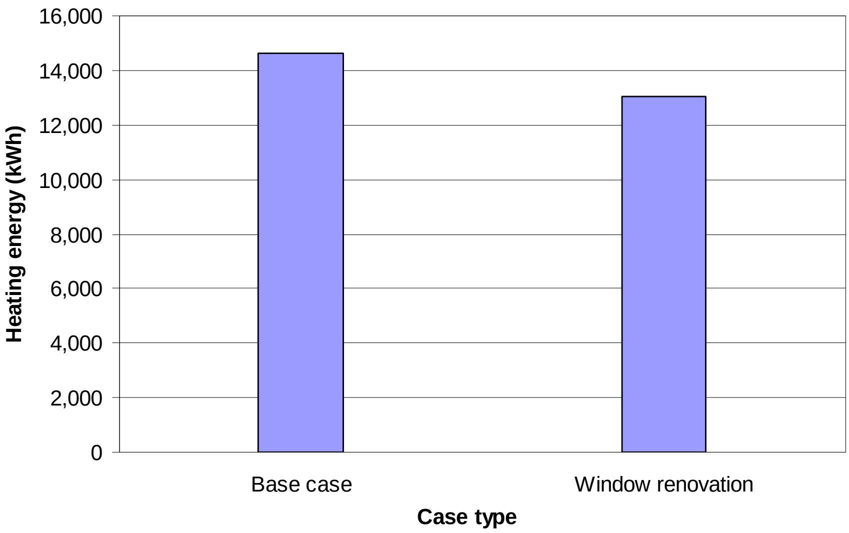

Figure 5.17: Energy savings of building for total heating energy (İstanbul)

5.4.1.4. Summer Period (15 May- 15 June) Calculations and Results

Temperatures of zones for base case, window renovation strategy; shading devices strategy and combined strategy (window renovation + shading devices) are calculated. (Figure 5.18, Figure 5.19, Figure 5.20, Figure 5.21) Cooling energy demand for each zones and total energy demand for building are calculated. In this calculation, it is assumed that comfort temperature is 26˚C and cooling system is working 5 days in one week, from the hour 7.00 to 17.00. It is assumed that space temperature is 30˚C in the rest hours of day and holidays. In real conditions building has not a mechanical ventilation system. It is assumed that natural ventilation is used and every break time classrooms are ventilated by opening windows.

Base Case

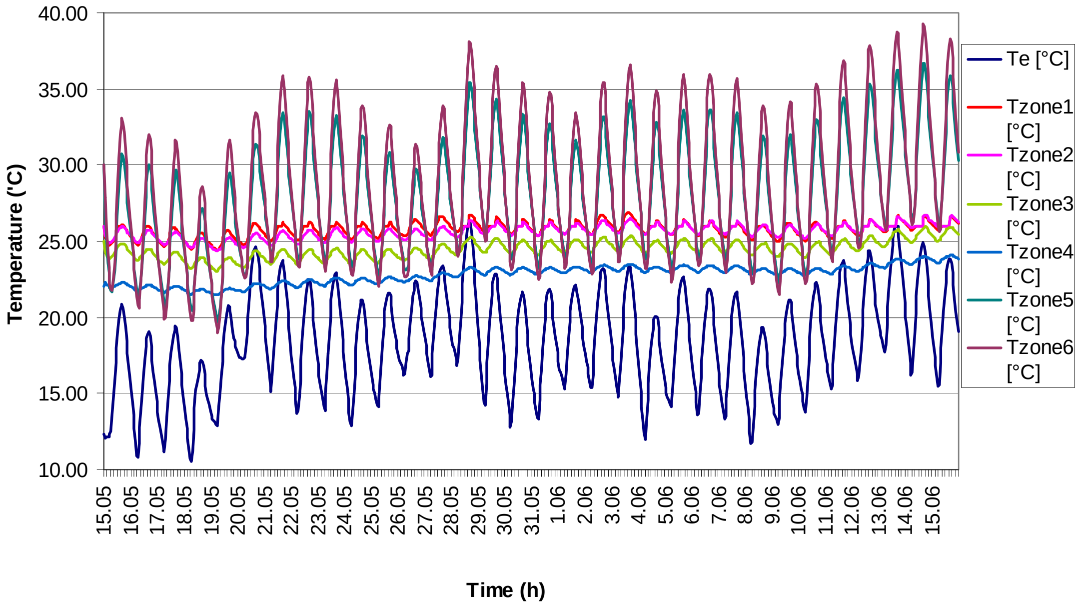

Figure 5.18: Temperatures of zones for base case in 15 May- 15 June (İstanbul)

Window Renovation

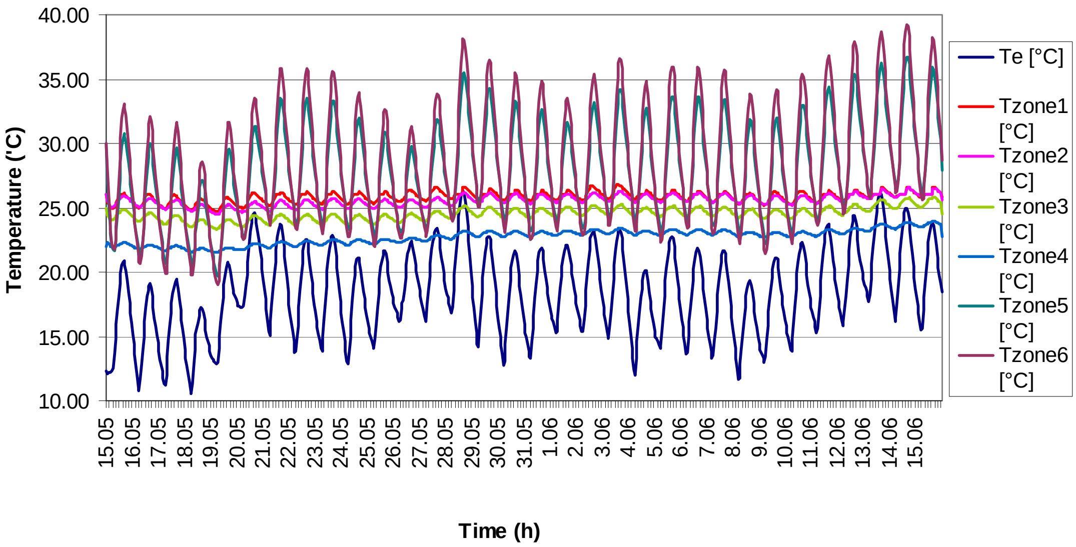

Figure 5.19: Temperatures of zones with window renovation in 15 May- 15 June (İstanbul)

In Zone 5 and Zone 6 cooling system is not working. Temperatures of these two zones are higher as it is seen in figures.

Shading Devices

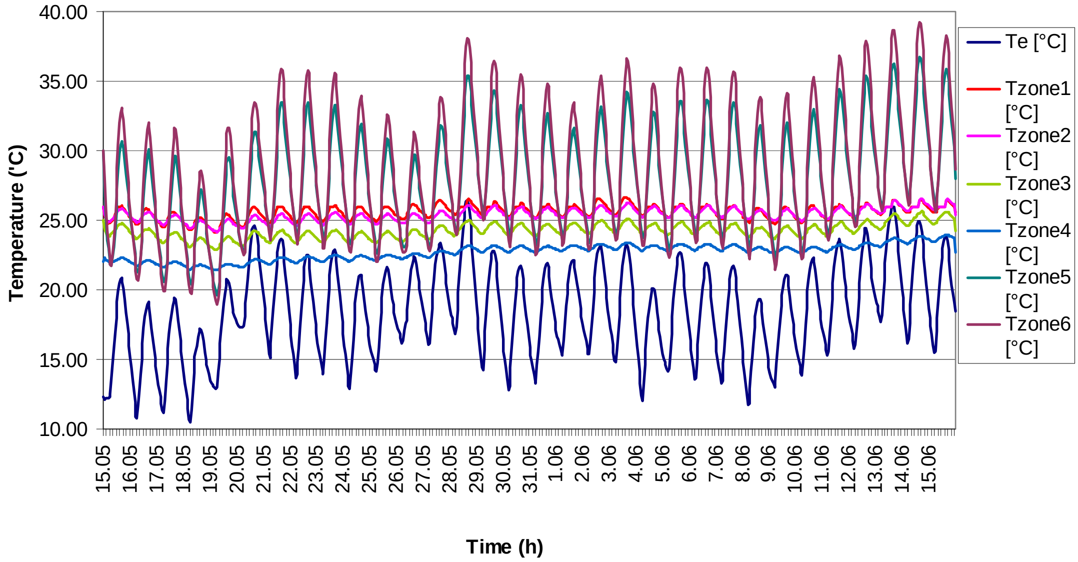

Figure 5.20: Temperatures of zones with shading devices in 15 May- 15 June (İstanbul)

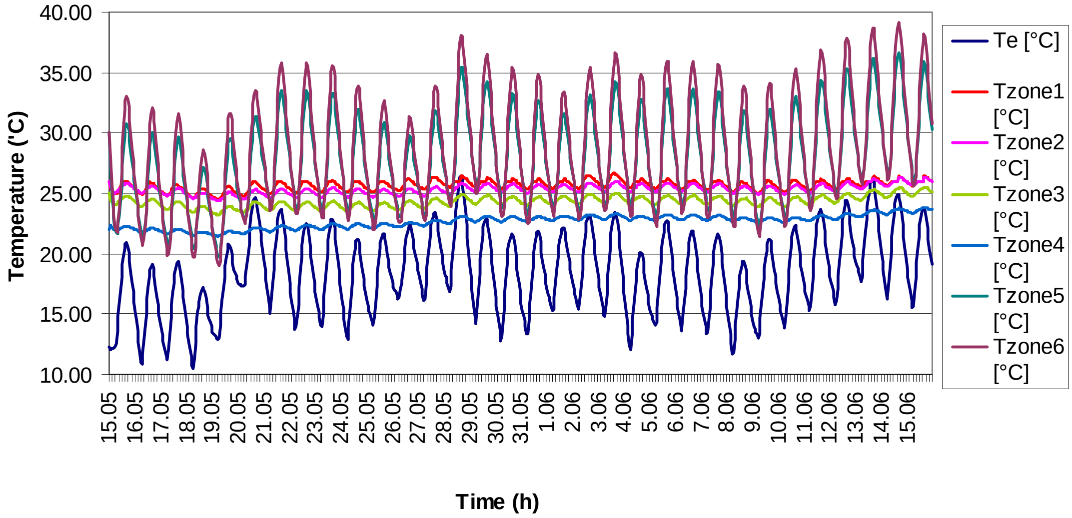

Figure 5.21: Temperatures of zones with combined strategy in 15 May- 15 June (İstanbul)

Average zone temperatures for base case, window renovation strategy shading devices strategy and combined strategy are seen in Table 5.10. Using low U-value window type and using shading devices do not cause so high differences at average temperatures but it has a positive effect reducing temperatures in cooled zones according to the base case. These renovations are more effective in total energy demand of building.

Table 5.10: Average temperatures of zones for each case in 15 May-15 June (İstanbul)

Case Type	15 May-15 June	T ambient	Zone1	Zone2	Zone3	Zone4	Zone5	Zone6
Base Case	Average (˚C)		25.75	25.61	24.45	22.78	27.96	28.71
Window Renovation	Average (˚C)		25.82	25.55	24.51	22.73	27.96	28.71
Shading Devices	Average (˚C)	18.45	25.56	25.39	24.22	22.68	27.94	28.69
Combined Strategy			25.66	25.32	24.30	22.64	27.94	28.69

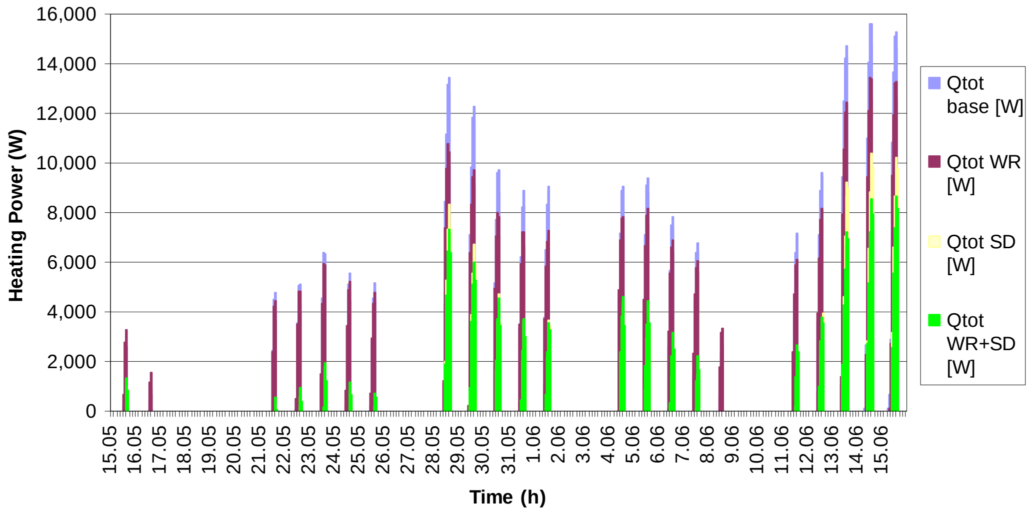

Figure 5.22: Hourly cooling energy demand in 15 May-15 June (İstanbul)

In Figure 5.22 hourly cooling energy demand is seen. Energy saving of combined strategy is more effective then the other strategies. Total energy demand and cooling load for cooling season are seen in Table 5.11. With shading devices strategy and combined strategy energy saving is % 60.

Table 5.11: Total energy demand of building for each case in 15 May- 15 June (İstanbul)

Case Type	Cooling Energy (kWh)	Cooling Load (kWh/m2)
Base Case	781.2	0.05
Window Renovation	700.6	0.04
Shading Devices	320.7	0.02
Combined Strategy	312.4	0.02

Table 5.12: Annually total energy demand and total energy load of building (İstanbul)

Case Type	Heating Energy (kWh)	Heating Load (kWh/m2)	Cooling Energy (kWh)	Cooling Load (kWh/m2)	Total Energy (kWh)	Total Load (kWh/m2)
Base Case	14638.5	0.94 (100)	781.2	0.05 (100)	15419.7	0.99 (100)
Window Renovation	13034.5	0.84 (89)	700.6	0.04 (80)	13735.1	0.88 (88)
Shading Devices	-	-	320.7	0.02 (40)	320.7	0.02 (40) (SP)
Combined Strategy	-	-	312.4	0.02 (40)	312.4	0.02 (SP) (40)

Heating and cooling load for each case for heating and cooling seasons are seen in Table 5.12. In heating season energy demand is reduced with window renovation strategy. For window renovation strategy energy savings for heating load is %11 according to the base case. In cooling season with window renovation energy saving for cooling season is %20, with shading devices energy saving is %60 according to the base case. In annually calculation for heating energy saving is %12 for window renovation. The energy saving with shading devices for annually calculations is equal only for the summer period because shading devices are not used in winter season period. When the shading devices are used only in cooling season (summer period) energy saving is %60 according to base case. With combined strategy, it has the same result %60 energy savings, like only using shading devices strategy. Nevertheless, window renovation is necessary for the heating season. So only using shading devices can have positive effect for cooling season but window renovation strategy is necessary for heating season and for the total energy savings.

5.4.2. Cold Climate (Erzurum)

Cold climate is effective in Erzurum. For Erzurum, only heating demand is investigated. Because of being in cold climate and even in summer time it needs heating demand; cooling demand in this city can be ignored. Increasing insulation thickness, window renovation strategy and using them together are investigated in this study for heating system.

5.4.2.1. Increasing Insulation Thickness

In existing project, insulation in exterior wall is 5 cm. In suggested project this insulation in exterior wall is 3 cm thicker than the existing one, it is assumed that the insulation thickness is 8 cm.

5.4.2.2. Window renovation

In existing project in all windows, window type, which has a U-value 2.83, is used. Optical properties of window are seen in Figure 5.10 and Figure 5.11.

5.4.2.3. Winter Period (January) Calculations and Results

Temperatures of zones for base case, window renovation strategies and increasing insulation thickness and combined strategy are calculated in this part. (Figure 5.23, Figure 5.24, Figure 5.25 and Figure 5.26) Heating energy demand for each zones and total energy demand for building are calculated. In this calculation, it is assumed that comfort temperature is 20˚C and heating system is working 5 days in one week, from the hour 7.00 to 17.00 It is assumed that space temperature is 15˚C in the rest hours of day and holidays. It is assumed that natural ventilation is used and every break time classrooms are ventilated by opening windows.

Base Case

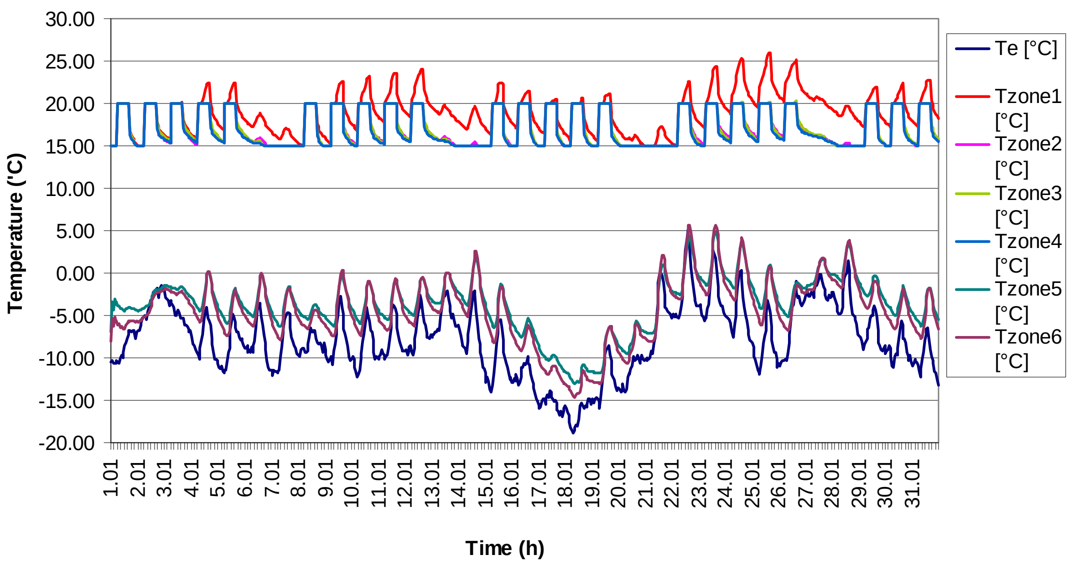

Figure 5.23: Temperatures of zones for base case in January (Erzurum)

Window Renovation

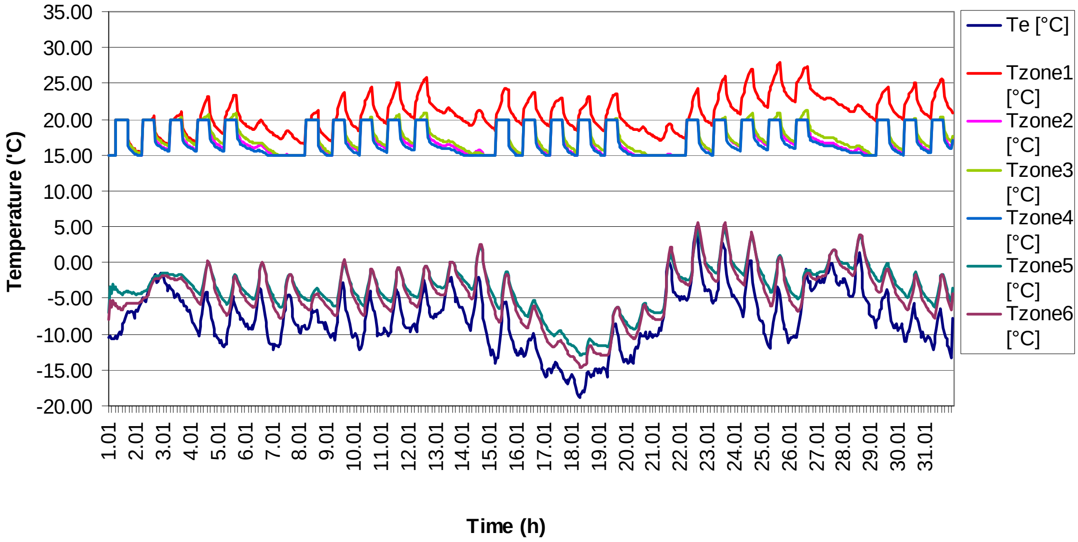

Figure 5.24: Temperatures of zones for window renovation in January (Erzurum)

Increasing Insulation Thickness

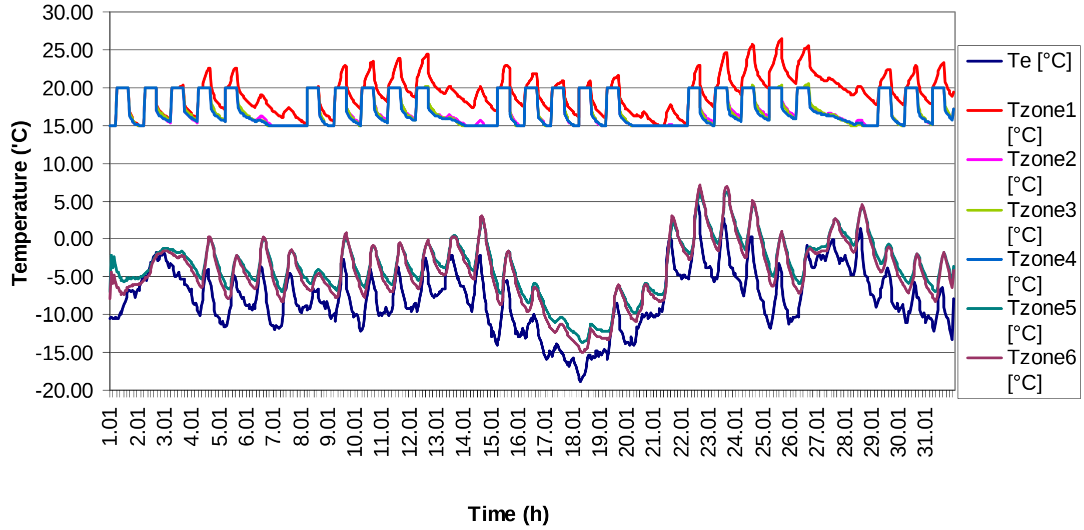

Figure 5.25: Temperatures of zones for increasing insulation thickness strategy in January (Erzurum)

After all these calculations for each strategy, temperatures of combined strategy are calculated. It is assumed that in combined strategy window renovation strategy and increasing insulation strategy used together.

Combined Strategy

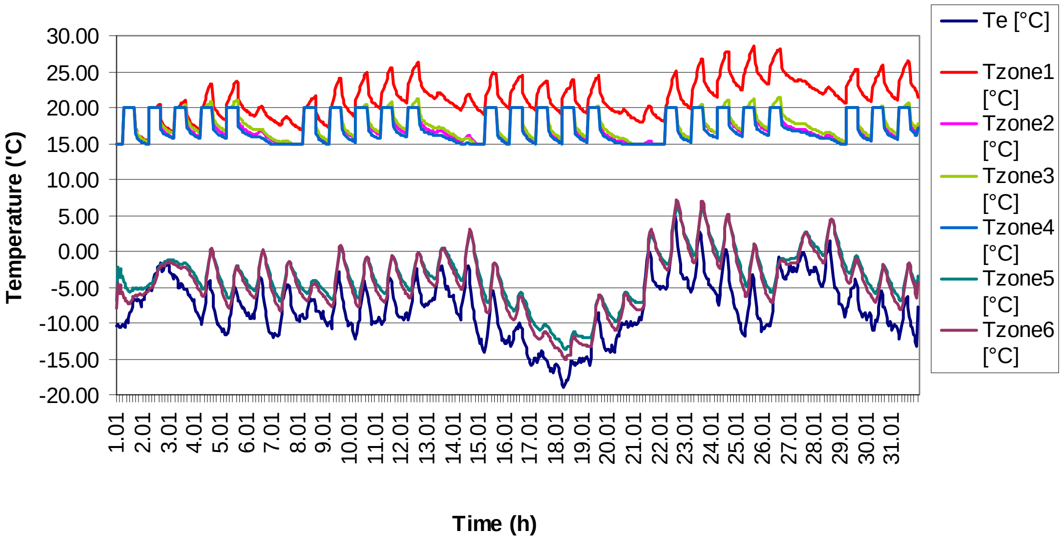

Figure 5.26: Temperatures of zones for combined strategy in January (Erzurum)

After temperature calculations average temperature of all zones for all case types are seen in Table 5.13.

Table 5.13: Average temperatures of zones for base case, window renovation, increasing insulation thickness strategy and combined strategy in January (Erzurum)

Case Type	Heating Season	T ambient	Zone1	Zone2	Zone3	Zone4	Zone5	Zone6
Base Case	Average (˚C)	-7.82	19.06	17.13	17.14	17.02	-3.65	-4.44
Window Renovation			20.81	17.32	17.62	17.11	-3.59	-4.42
Increasing Insulation Thickness			19.36	17.22	17.20	17.10	-3.61	-4.26
Combined Strategy			21.38	17.46	17.76	17.21	-3.54	-4.25

Average temperatures of heated zones with window renovation strategy, increasing insulation thickness strategy and combined strategy are higher then base case as it is seen in Table 5.13. With combines strategy in Zone 1 average temperature is nearly 2˚C higher then base case. In other zones, maximum average temperatures also can be got by combined strategy. Temperature calculations for Zone 1 for all case type are seen in Figure 5.27. According to these calculations, with combined strategy average temperatures of Zone 1 are 2- 3˚C higher then average temperature of base case. (Figure 5.27)

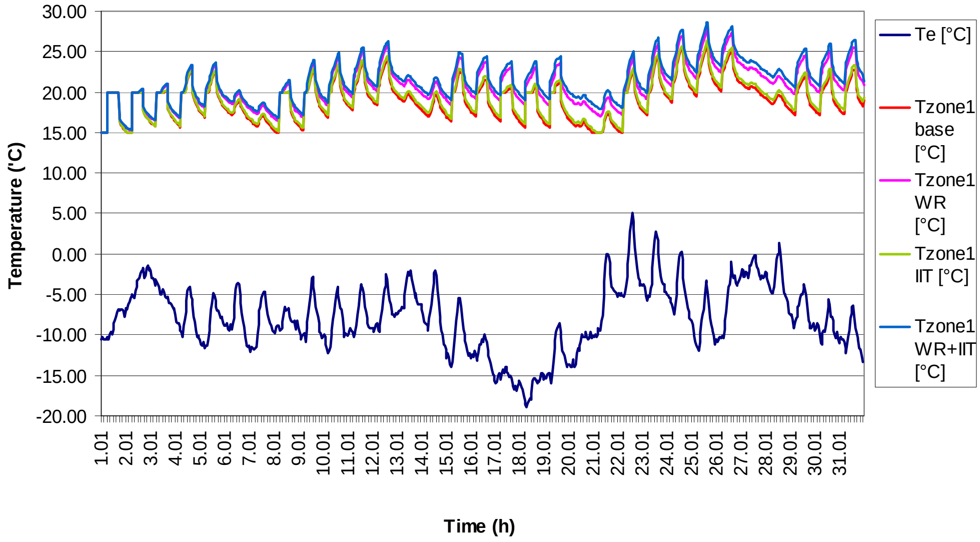

Figure 5.27: Temperature of zone 1 for base case, window renovation, increasing insulation thickness renovation and combined strategy (Erzurum)

Table 5.14: Heating demand of zones for base case, with window renovation increasing insulation thickness strategy and combined strategy in January (Erzurum)

Thermal Zones	Case Type	Heating Energy (kWh)	Heating Load (kWh/m2)
	Base Case	1602.9	0.35
Zone 1	Window Renovation	620.2	0.13
	Increasing Insulation Thickness	1303.5	0.28
	Combined Strategy (WR+IIT)	566.7	0.12
	Base Case	6459.0	2.81
Zone 2	Window Renovation	5472.2	2.38
	Increasing Insulation Thickness	5976.3	2.60
	Combined Strategy(WR+IIT)	4997.9	2.17
	Base Case	5989.0	1.69
	Window Renovation	3099.8	0.87
Zone 3	Increasing Insulation Thickness	5455.3	1.54
	Combined Strategy(WR+IIT)	2620.5	0.74
	Base Case	18739.2	3.62
	Window Renovation	17481.1	3.38
Zone 4	Increasing Insulation Thickness	17620.0	3.41
	Combined Strategy (WR+IIT)	16307.1	3.15

With renovation strategies, heating energy demand and heating load are reduced. Every renovation strategy has a positive effect when they are only used, but with combined strategy energy savings are higher. (Table 5.14) Total heating load saving is %26 when combined strategy is used. (Table 5.15)

Table 5.15: Total heating energy and heating load in January (Erzurum)

Case Types	Total Heating Energy (kWh)	Total Heating Load (kWh/m2)
Base Case	32790.2	2.11 (100)
Window Renovation	26673.3	1.71 (81)
Increasing Insulation Thickness	30355.2	1.95 (92)
Combined Strategy (WR+IIT)	24492.2	1.57 (74)

In Figure 5.28 hourly total heating powers are seen, Figure 5.29 represents total heating demand. As it is seen in figure hourly heating power with window renovation strategy, with increasing insulation strategy and with combined strategy are less then base case. When all strategies compared with combined strategy, heating power has maximum reduction according to the base case.

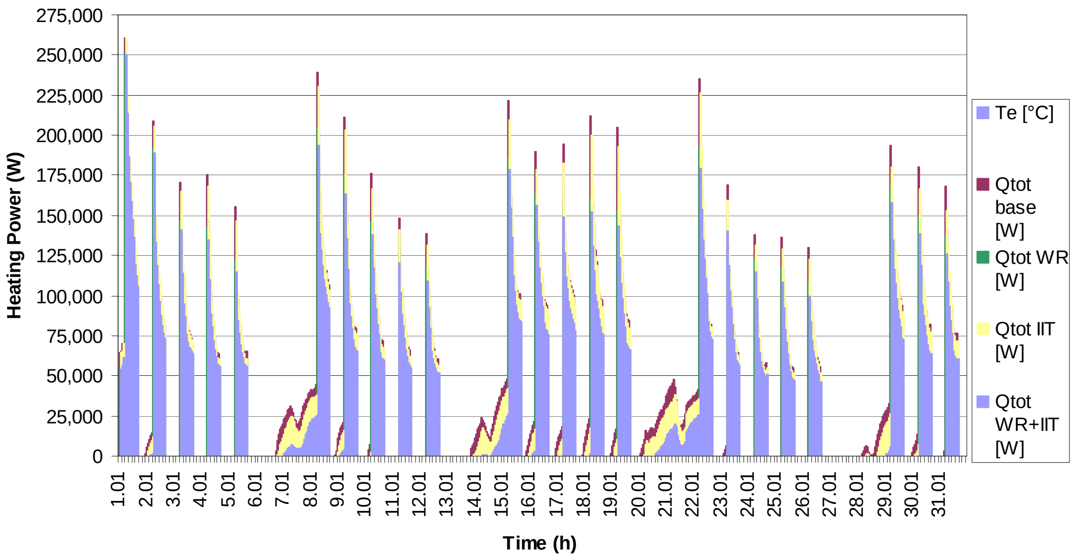

Figure 5.28: Hourly heating power for base case , window renovation strategy, increasing insulation thickness strategy and combined strategy (Erzurum)

Figure 5.29 represents total heating demand. Energy savings are %19 with window renovation, %8 with increasing insulation thickness renovation and %26 with the combined strategy.(Table 5.15)

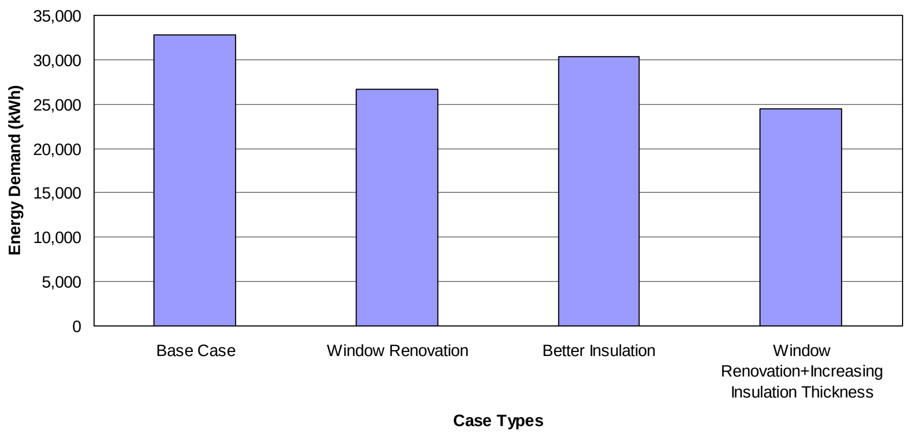

Figure 5.29: Total heating energy in January (Erzurum)

5.4.3. Mild-Dry Climate (Ankara)

Characteristic city for mild-dry climate is Ankara. In Ankara both heating and cooling demand are investigated. Increasing insulation thickness, window renovation; shading devices and using them together are investigated in this study.

5.4.3.1. Window Renovation

In existing project in all windows, window type which has an U-value 2.83 is used. Optical properties of window are seen in Figure 5.10, Figure 5.11.

5.4.3.2. Increasing Insulation Thickness

In existing project insulation in exterior wall is 5 cm. In suggested project this insulation in exterior wall is 3 cm thicker than the existing one, it is assumed that the insulation thickness is 8 cm.

5.4.3.3. Shading Devices

In existing building shading devices are not used. In suggested application, shading devices are used with shading factor 0.2. Occupancy hours are Monday to Friday, from 12.00 -16.00 pm. In heating period, it is assumed that the shading devices are not working. Shading devices does not transfer sun light. In school especially for classroom light is so important for comfort conditions for these reasons, shading factor has been taken 0.2. Shading device properties can be seen in Figure 5.12

5.4.3.4. Winter Period (January) Calculations and Results

In Figure 5.30 temperatures of zones for base case, in Figure 5.31 temperatures for window renovation, in Figure 5.32 temperatures of zones for increasing insulation thickness strategy, in Figure 5.33 temperatures of zones for combined strategy are seen. Temperatures are calculated for every hour for January. In winter time temperatures of zones especially zone 1 are high during the afternoon hours. For example in classrooms, temperatures are nearly 30˚C or higher. In fact in real conditions building has not a mechanical ventilation system, but in this calculation it is assumed that there is mechanical ventilation system in building for all case types including base case. It is effective especially in zone 1 for to get comfortable conditions. The air is supplied with an air change rate 0.95 1/h. Operating hours for ventilation system is from 12.00 to 15.00 during the school days. Supply air temperature is adjusted as outside temperature.

Base Case

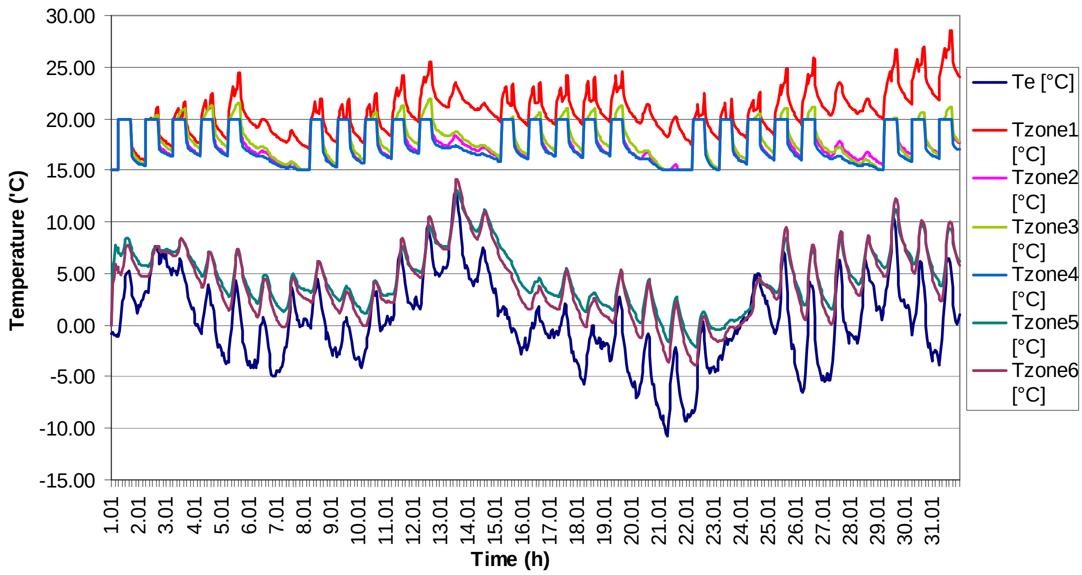

Figure 5.30: Temperatures of zones for base case in January (Ankara)

As it is seen in figures with renovation strategies temperatures of zones are higher according to the base case. With combined strategy which means using window renovation and increasing insulation thickness together, increase of these temperatures are maximum.

Window Renovation

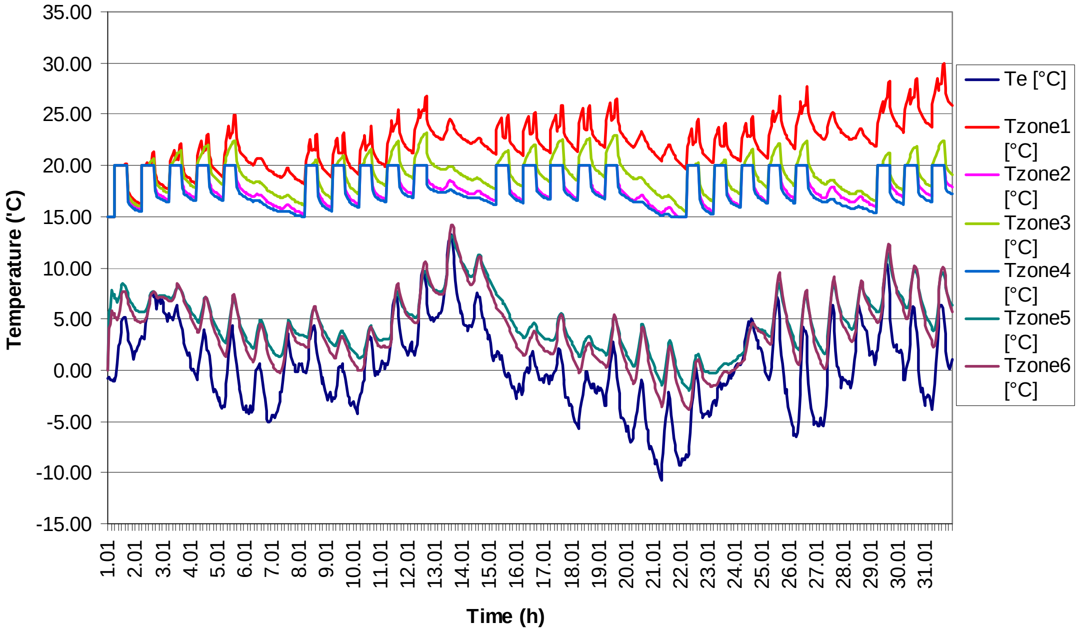

Figure 5.31: Temperatures of zones for window renovation in January (Ankara)

Increasing Insulation Thickness

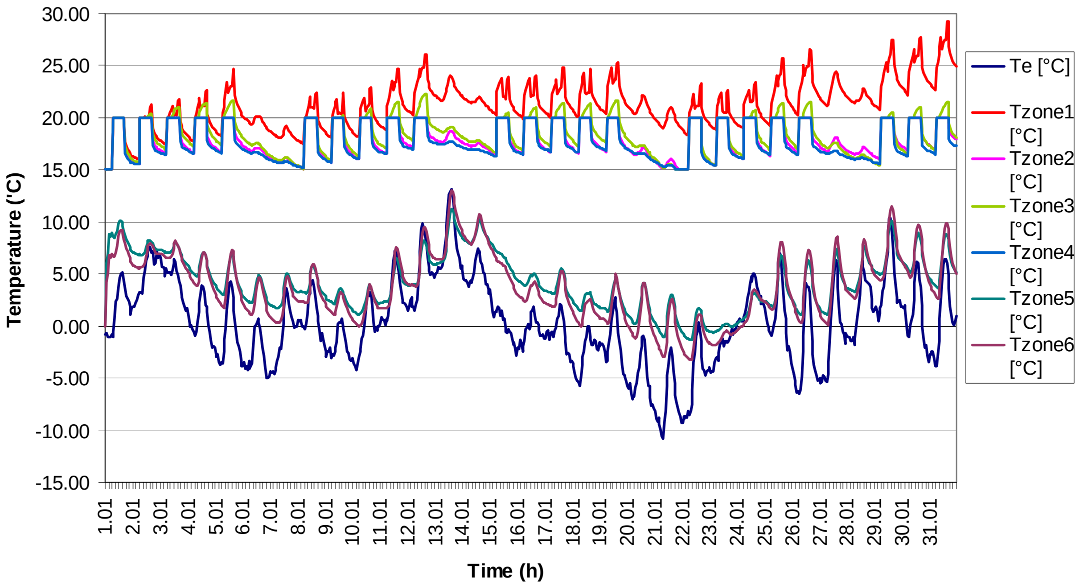

Figure 5.32: Temperatures of zones for increasing insulation thickness strategy in January (Ankara)

Combined Strategy

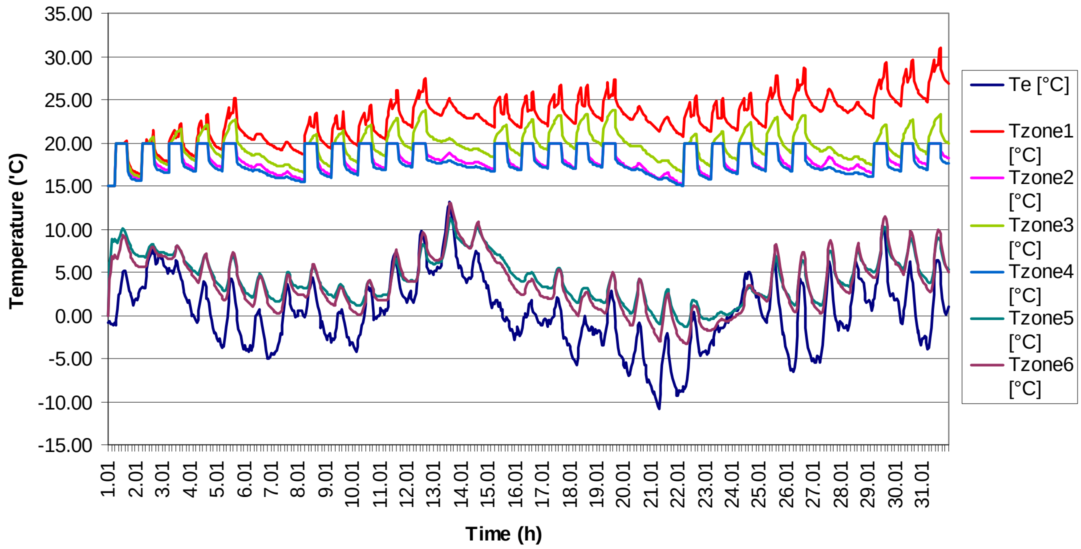

Figure 5.33: Temperatures of zones for combined strategy in January (Ankara)

Temperatures with combined strategy are the highest for zone 1 as it is seen in Figure 5.34. In some period of the calculations temperatures of combined strategy are 2- 4 ˚C higher then the temperatures of base case.

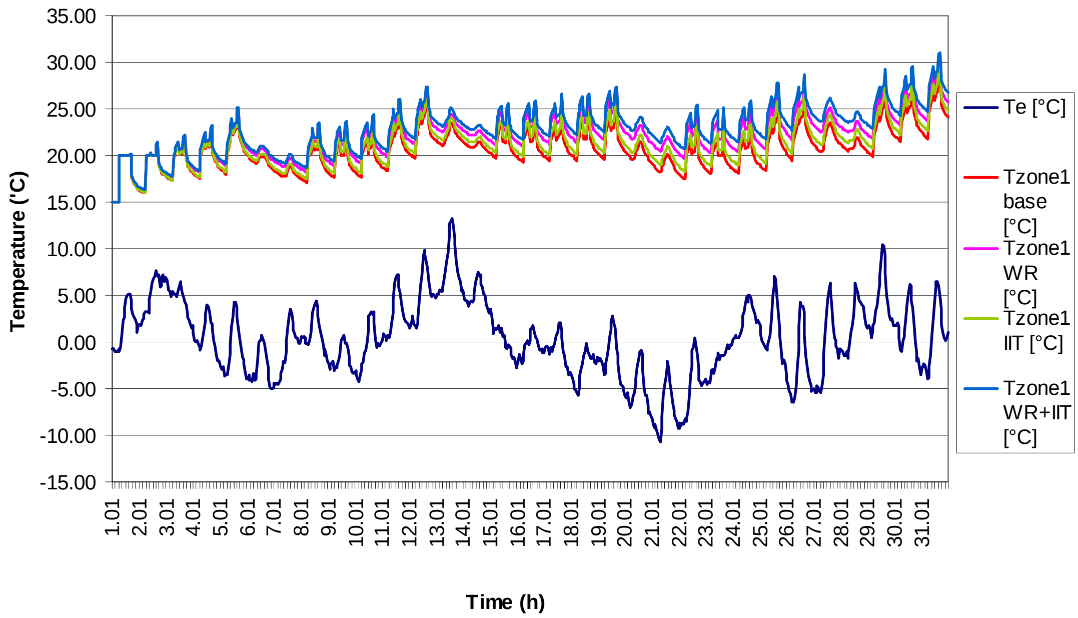

Figure 5.34: Temperatures of Zone 1 for base case, window renovation, increasing insulation thickness and combined strategy in January (Ankara)

Average temperature of all zones for all case types are seen in Table 5.16. In zone 1 with combined strategy average temperature is 1.3 ˚C higher then average temperatures for base case. Hourly heating power of building in January is seen in Figure 5.35.

Table 5.16: Average temperatures of zones for window renovation strategy increasing insulation thickness strategy and combined strategy in January (Ankara)

Case Type	Heating Season	T ambient	Zone1	Zone2	Zone3	Zone4	Zone5	Zone6
Base Case	Average (˚C)	0.10	19.55	16.33	16.38	15.99	3.10	2.86
Window Renovation	Average (˚C)		20.39	16.45	17.07	16.11	3.16	2.87
Increasing Insulation Thickness	Average (˚C)		19.94	16.47	16.56	16.14	2.59	2.51
Combined Strategy	Average (˚C)		20.91	16.60	17.47	16.28	2.66	2.53

With renovation strategies, heating energy demand and heating load are reduced. With combined strategy energy saving is % 30 in zone 1, %25 in zone 2, % 79 in zone 3 and %15 in zone 4.(Table 5.17)

Table 5.17: Heating energy demand and heating energy load for window renovation strategy, increasing insulation thickness strategy and combined strategy in January (Ankara)

Thermal Zones	Case Type	Heating Energy (kWh)	Heating Load (kWh/m2)
Zone 1	Base Case	461.2	0.10
	Window Renovation	357.2	0.07
	Increasing Insulation Thickness	422.1	0.09
	Combined Strategy	350.1	0.07
Zone 2	Base Case	4218.3	1.83
	Window Renovation	3675.4	1.59
	Increasing Insulation Thickness	3720.5	1.61
	Combined Strategy	3163.4	1.37
Zone 3	Base Case	1845.7	0.52
	Window Renovation	616.6	0.17
	Increasing Insulation Thickness	1404.6	0.39
	Combined Strategy	421.8	0.11
Zone 4	Base Case	13724.5	2.65
	Window Renovation	12825.3	2.48
	Increasing Insulation Thickness	12672.7	2.45
	Combined Strategy	11730.4	2.27

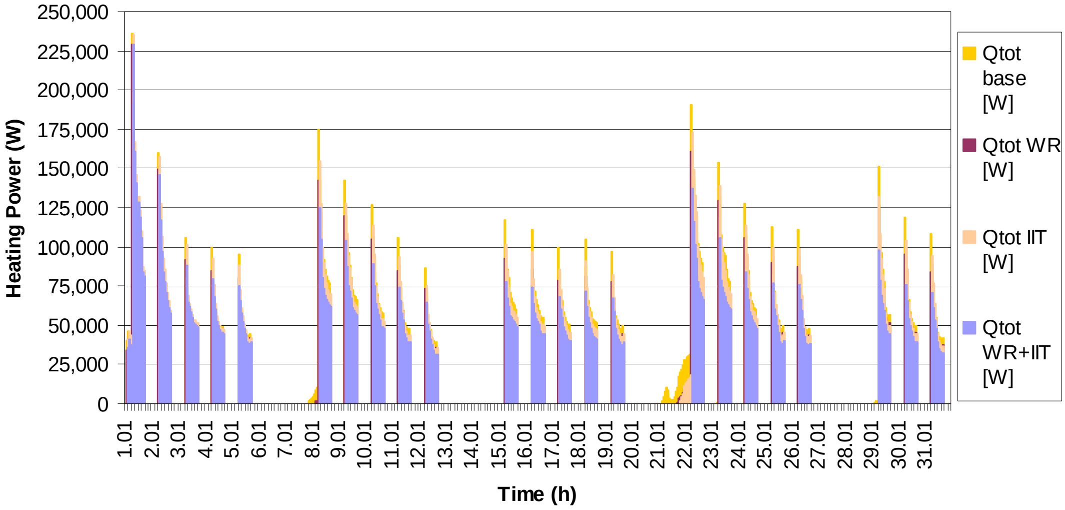

Figure 5.35: Hourly heating energy power for base case, window renovation strategy and increasing insulation thickness strategy in January (Ankara)

Table 5.18: Total heating energy demand and heating energy load in January (Ankara)

Case Types	Total Heating Energy (kWh)	Total Heating Load (kWh/m2)
Base Case	20249.8	1.30
Window Renovation	17474.5	1.12
Increasing Insulation Thickness	18219.9	1.17
Combined Strategy (WR+IIT)	15665.7	1.01

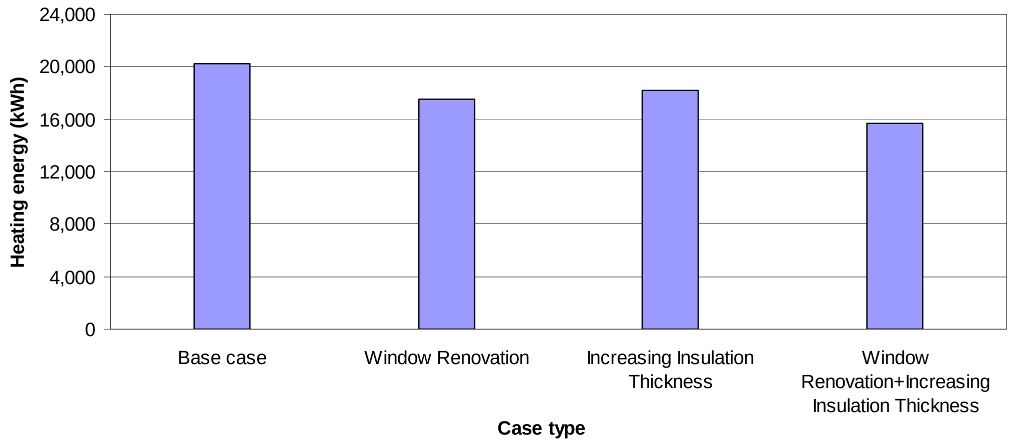

Figure 5.36: Total heating energy demand for each case in January (Ankara)

Total heating energy and heating load are reduced with renovation strategies. With combined strategy, total heating energy demand has maximum reduction. (Figure 5.36) Energy savings is %23 when combined strategy is used. (Table 5.18)

5.4.3.5. Summer Period (15 May- 15 June) Calculations and Results

Temperatures of zones for base case, window renovation strategy, increasing insulation thickness strategy, shading devices strategy and combined strategy are calculated. (Figure 5.37, Figure 5.38, Figure 5.39, Figure 5.40, Figure 5.41) Cooling energy demand for each zones and total energy demand for building are calculated. Temperatures are taken every hour in 15 May-15 June period. In this calculation, it is assumed that comfort temperature is 26˚C and cooling system is working 5 days in one week, from the hour 7.00 to 17.00. It is assumed that space temperature is 30˚C in the rest hours of day and holidays. It is assumed that natural ventilation is used and every break time classrooms are ventilated by opening windows.

Base Case

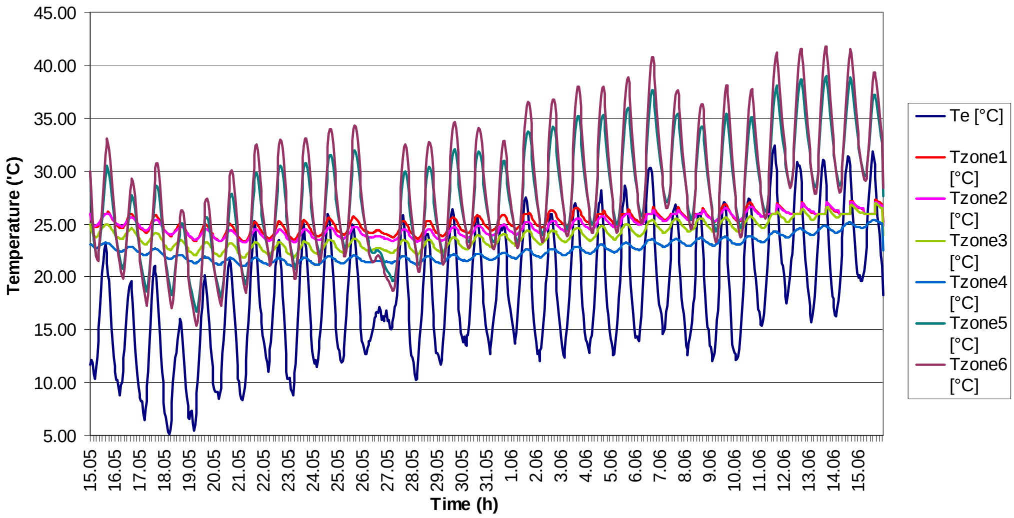

Figure 5.37: Temperature of zones for base case in 15 May-15 June (Ankara)

As it is seen in figures using shading devices and using combined strategy has more reduction in temperatures in zones during 15 May-15 June period according to the base case.

Window Renovation

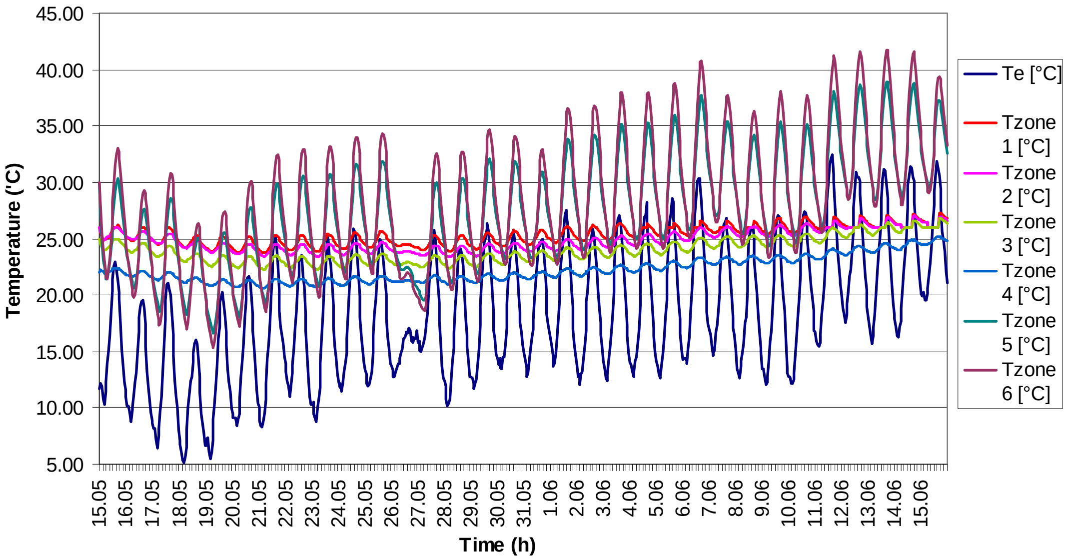

Figure 5.38: Temperatures of zones for window renovation in 15 May-15 June (Ankara)

Cooling system is effective in Zone 1, Zone 2, Zone 3 and Zone 4. Zone 5 and Zone 6 represent the roof parts and cooling system is not active in this parts. Temperatures of these zones reach above 40 ˚C as it is seen in the figures.

Increasing Insulation Thickness

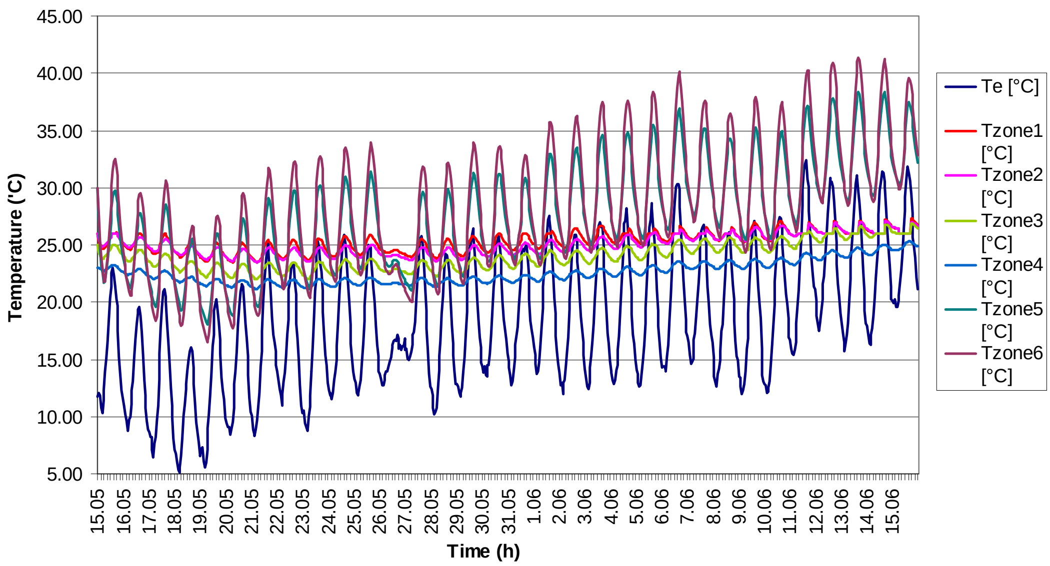

Figure 5.39: Temperatures of zones for increasing insulation thickness strategy in 15 May-15 June (Ankara)

Shading Devices

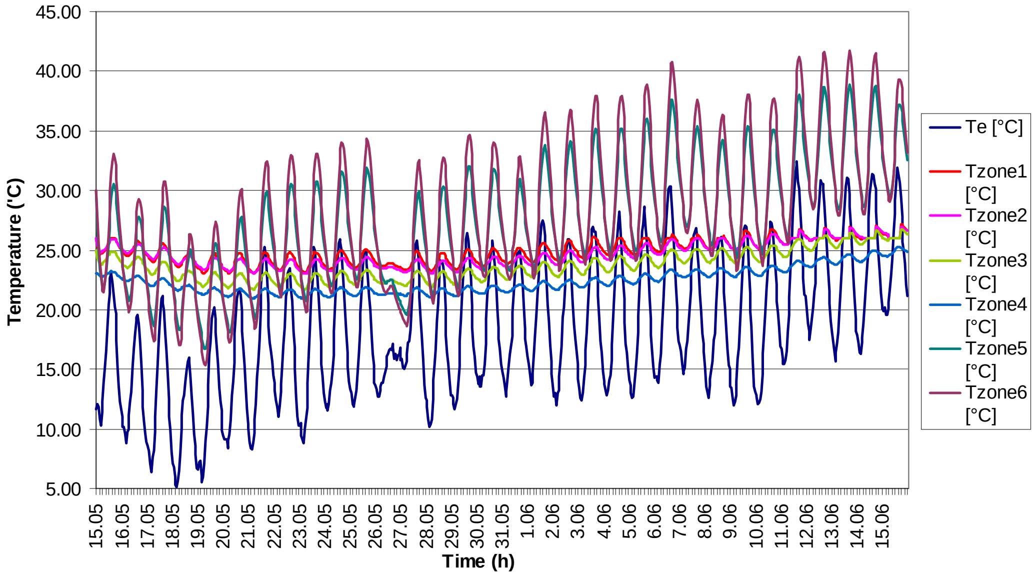

Figure 5.40: Temperatures of zones for shading devices in 15 May-15 June (Ankara)

Combined Strategy

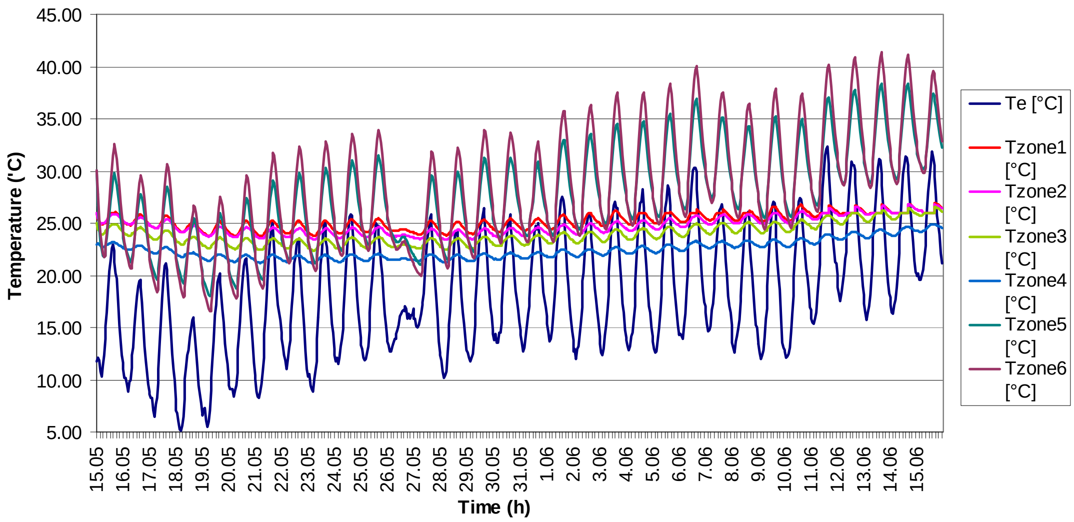

Figure 5.41: Temperatures of zones for combined strategy in 15 May-15 June (Ankara)

There is not so high differences average temperatures of zones. (Table 5.19)

Table 5.19: Average temperatures of zones for window renovation strategy, increasing insulation thickness strategy, shading devices strategy and combined strategy 15 May-15 June (Ankara)

Case Type	Cooling Season	T ambient	Zone1	Zone2	Zone3	Zone4	Zone5	Zone6
Base Case			25.19	24.87	23.90	22.52	27.65	28.37
Window Renovation			25.31	24.84	23.95	22.22	27.63	28.37
Increasing Insulation Thickness	Average (˚C)	16.4	25.30	25.03	24.00	22.59	27.61	28.36
Shading Devices			24.88	24.64	23.68	22.39	27.63	28.36
Combined Strategy			25.17	24.75	23.92	22.44	27.61	28.35

With renovation strategies cooling energy demand and cooling load are reduced. With combined strategy energy saving is %40 in zone 1, % 50 in zones 2, and % 60 in zone 3. (Table 5.20) For zone 4 there is no cooling demand. Hourly cooling energy power can be seen in Figure 5.42. Total energy savings for cooling period is %45 with combined strategy.(Figure 5.43)

Energy savings of zones can be seen in Table 5.21. Using combined strategy for cooling system has more energy savings as it is seen in Figure 5.43

Table 5.20: Cooling energy demand and cooling load for base case, window renovation strategy, increasing insulation thickness and combined strategy in 15 May-15 June (Ankara)

Thermal Zones	Case Type	Cooling Energy (kWh)	Cooling Load (kWh/m2)
	Base Case	942.8	0.20
Zone 1	Window Renovation	723.7	0.16
	Increasing Insulation Thickness	992.0	0.21
	Shading Devices	618.9	0.13
	Combined Strategy (WR+IIT+SD)	563.8	0.12
	Base Case	284.1	0.12
Zone 2	Window Renovation	177.3	0.07
	Increasing Insulation Thickness	297.2	0.12
	Shading Devices	201.2	0.08
	Combined Strategy(WR+IIT+SD)	144.0	0.06
	Base Case	207.1	0.05
	Window Renovation	107.7	0.03
Zone 3	Increasing Insulation Thickness	212.3	0.06
	Shading Devices	133.6	0.03
	Combined Strategy(WR+IIT+SD)	76.3	0.02

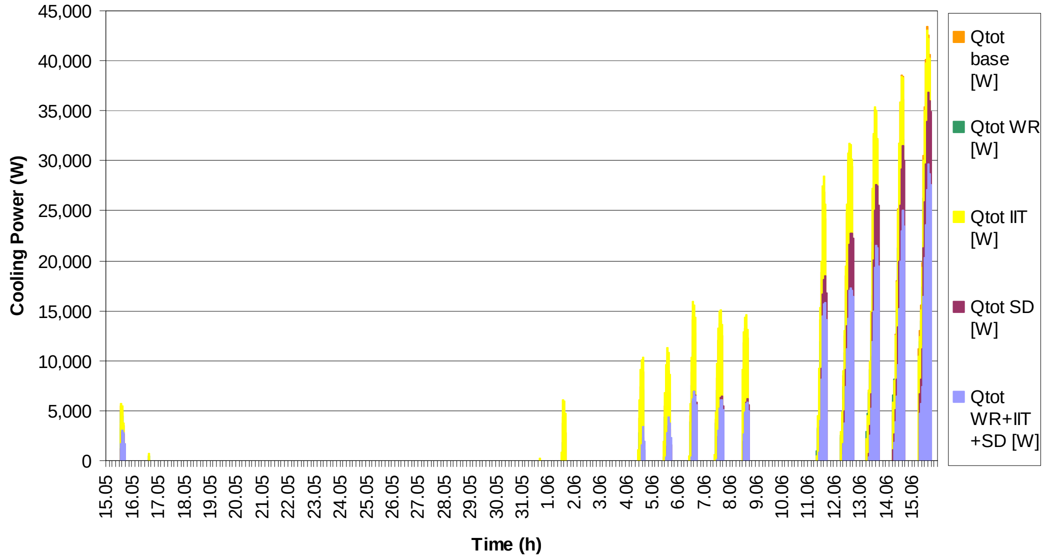

Figure 5.42: Hourly cooling power for each cases (Ankara)

Table 5.21: Total cooling energy demand and total cooling load of building (Ankara)

Case Types	Total Cooling Energy (kWh)	Total Cooling Load (kWh/m2)
Base Case	1434.1	0.09
Window Renovation	1008.8	0.06
Increasing Insulation Thickness	1501.4	0.09
Shading Devices	953.6	0.06
Combined Strategy (WR+IIT+SD)	784.0	0.05

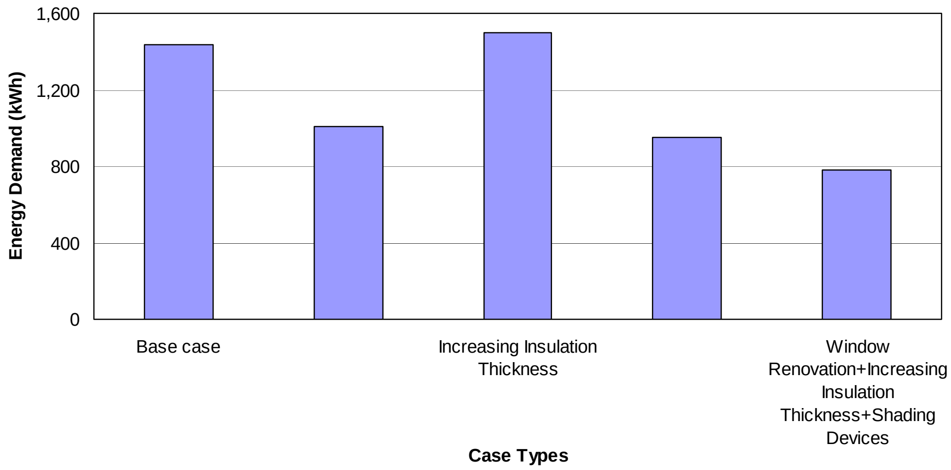

Figure 5.43: Total cooling energy demand of each case in 15 May- 15 June (Ankara)

Table 5.22: Annually total energy demand and total energy load (Ankara)

Case Type	Heating Energy (kWh)	Heating Load (kWh/m2)	Cooling Energy (kWh)	Cooling Load (kWh/m2)	Total Energy (kWh)	Total Load (kWh/m2)
Base Case	20249.8	1.30 (100)	1434.1	0.09 (100)	21683.9	1.39 (100)
With Window Renovation	17474.5	1.12 (86)	1008.8	0.06 (66)	18483.3	1.19 (85)
Increasing Insulation Thickness	18219.9	1.17 (90)	1501.4	0.09 (100)	19721.3	1.27 (91)
Shading Devices	-	-	953.6	0.06 (66) (SP)	953.6	0.06 (66) (SP)
Combined Strategy	15665.7	1.01 (77)	784.0	0.05 (55)	16449.7	1.06 (76)

Heating and cooling load for each case for heating and cooling seasons are seen in Table 5.22. In heating season, energy demand is reduced with window renovation and insulation thickness renovation. With window renovation situation energy saving is %14, with increasing insulation thickness renovation energy savings is % 10 and with combined strategy (window renovation and increasing insulation thickness) energy savings are %33 according to the base case. In cooling season with window renovation energy saving is % 34, with shading devices energy saving is %34, with combined strategy (window renovation, increasing insulation thickness and shading devices) energy saving is % 45 according to the base case. In cooling season, increasing insulation thickness renovation has a negative effect, which increases the cooling demand nearly 67.3 kWh. Because increasing insulation thickness obstructs the night cooling. But this negative effect is not seen in cooling load. In annually calculation for heating energy saving is %15 for window renovation, %9 for increasing insulation thickness and %24 for combined strategy. Combined strategy for summer period means window renovation, increasing insulation thickness and shading devices. Shading devices are not used in winter time. For this reason the energy saving with shading devices for annually calculations is equal only for the summer period. When the shading devices are used only in cooling season energy saving is % 34 according to base case. When combined strategy (window renovation and shading devices) is used in cooling season (summer period) energy saving is % 45. Total cooling energy demand of building can be seen in Figure 5.44.

5.4.4. Hot-Humid Climate (Antalya)

Characteristic city for hot-humid climate is Antalya. For Antalya both heating and cooling demand are investigated. Using window renovation for heating system and using window renovation, shading devices and using them together in cooling season are investigated.

5.4.4.1. Window Renovation

In existing project in all windows, window type which has an U-value 2.83 is used. For window renovation window type which has an U-value 1.24 is used. Optical properties of window are seen in Figure 5.10 and Figure 5.11.

5.4.4.2. Shading Devices

In existing building shading devices are not used. In suggestion application, shading devices are used with shading factor 0.2. Occupancy hours are Monday to Friday, from 12.00 -16.00 pm. In heating period, it is assumed that the shading devices are not working. Shading devices does not transfer sun light. In schools especially for classrooms light is so important for comfort conditions, for these reasons, shading factor has been taken 0.2. Shading device properties can be seen in Figure 5.12.

5.4.4.3. Winter Period Calculations and Results

In Figure 5.44 temperatures of zones for base case, in Figure 5.45 temperatures for window renovation are seen. Heating energy demand for each zones and total energy demand for building are calculated. In this calculation, it is assumed that comfort temperature is 20˚C and heating system is working 5 days in one week, from the hour 7.00 to 17.00 It is assumed that space temperature is 15˚C in the rest hours of day and holidays. In fact the school building has not a mechanical ventilation system. But in this study it is assumed that there is a mechanical ventilation system in building for each cases including base case. It is effective especially in zone 1 in where classroom temperatures are not in comfortable conditions. Without ventilation, indoor temperatures reach to 35 ˚C in some periods. The air is supplied with an air change rate 0.95 1/h. Operating hours for ventilation system is from 7.00 to 17.00 during the school days. Supply air temperature is adjusted as outside temperature.

Base Case

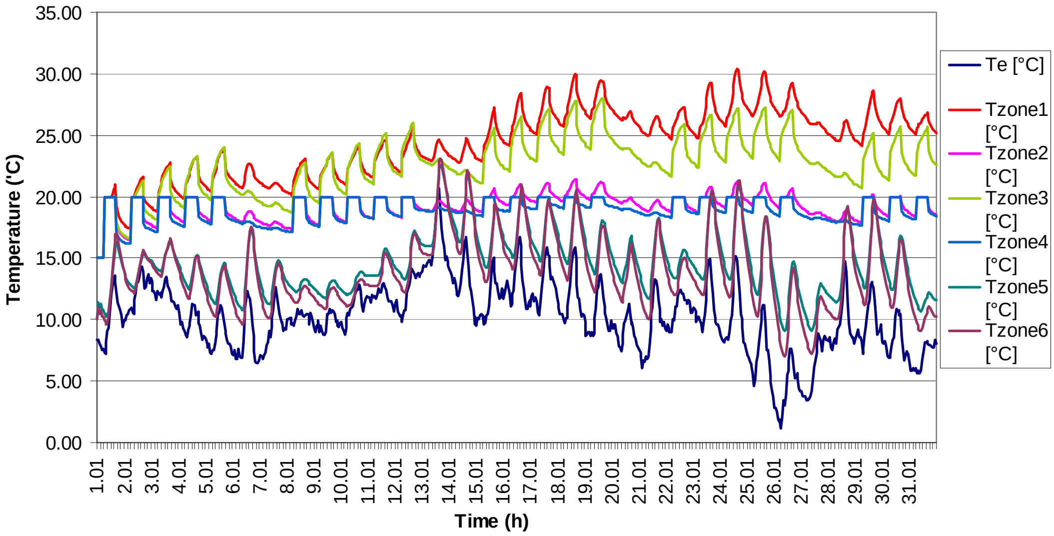

Figure 5.44: Temperatures of zones for base case in January (Antalya)

Window Renovation

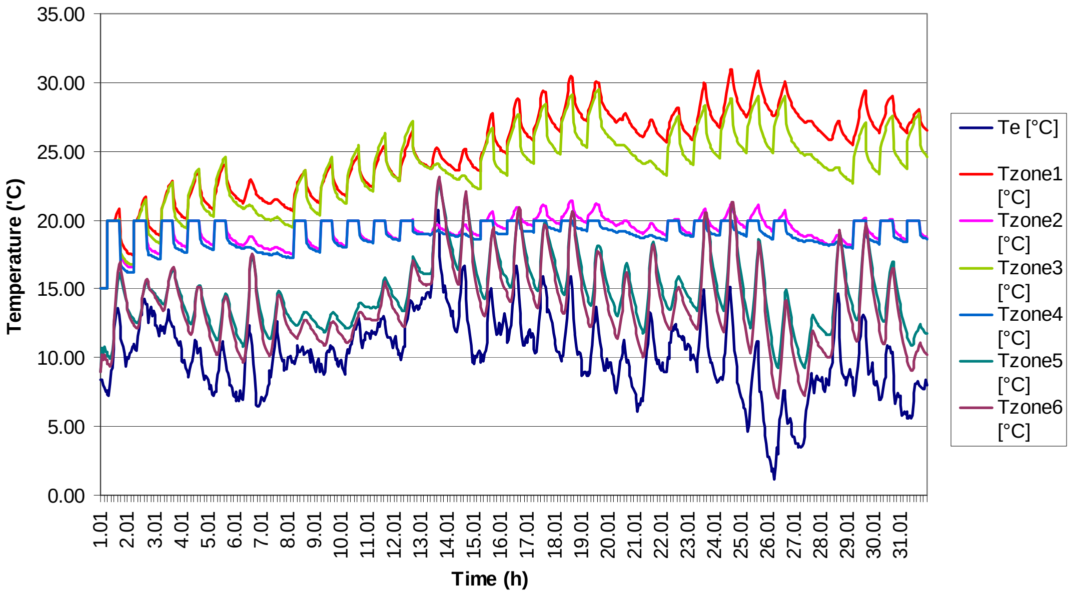

Figure 5.45: Temperatures of zones for window renovation in January (Antalya)

Average temperatures of zones are not so different from each other according to the base case and window renovation strategy. (Table 5.23) With window renovation, strategy there is reduction in hourly energy demand as it is seen in Figure 5.46.

Table 5.23: Average temperature of zones for base case and window renovation strategy in January (Antalya)

Case Type	Heating Season	T ambient	Zone1	Zone2	Zone3	Zone4	Zone5	Zone6
Base Case	Average (˚C)	10.24	24.33	19.25	22.64	18.89	14.62	13.88
Window Renovation			25.05	1932	23.88	18.99	14.72	13.88

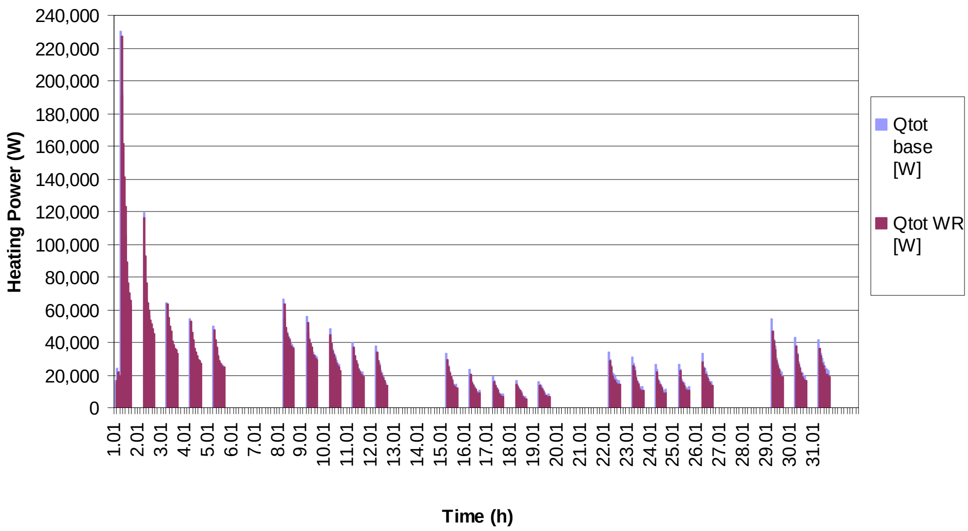

Figure 5.46: Hourly heating power of zones for each case in January (Antalya)

Table 5.24: Heating energy demand and heating load of zones in January (Antalya)

Thermal Zones	Case Type	Heating Energy (kWh)	Heating Load (kWh/m2)
Zone 1	Base case	288.0	0.06
	Window renovation	275.9	0.06
Zone 2	Base case	1213.4	0.52
	Window renovation	1077.7	0.46
Zone 3	Base case	219.1	0.06
	Window renovation	198.6	0.05
Zone 4	Base case	6329.3	1.22
	Window renovation	5848.8	1.13

There is reduction in heating energy load of zones as it is seen in Table 5.24.

Table 5.25: Total heating energy and heating load in January (Antalya)

Case Types	Total Heating Energy (kWh)	Total Heating Load (kWh/m2)
Base Case	8049.9	0.51
Window Renovation	7401.0	0.47

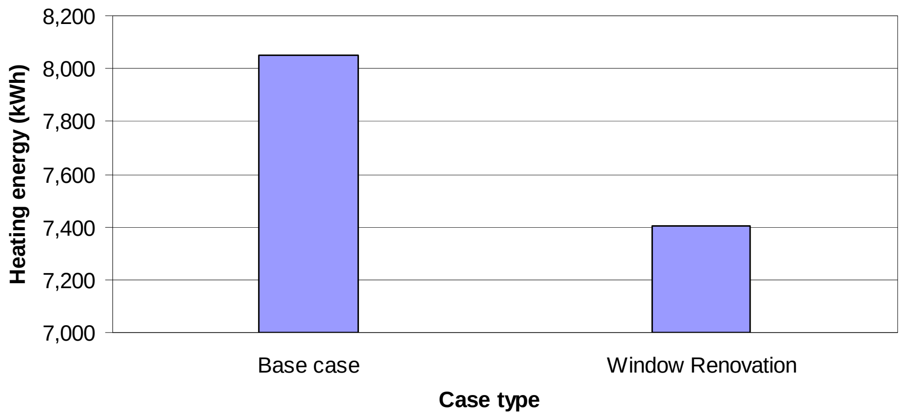

Figure 5.47: Total energy demand for each case in January (Antalya)

In Table 5.25 total heating energy demand and heating load can be seen. With window renovation energy savings in January is % 8. Total energy reduction according to the case types can be seen in Figure 5.47.

5.4.4.4. Summer Period (15 May-15 June) Calculations and Results

Calculations for base case , window renovation, shading devices and combined strategy are calculated in 15 May- 15 June period. (Figure 5.48, Figure 5.49, Figure 5.50 and Figure 5.51) Cooling energy demand for each zones and total energy demand for building are calculated. Temperatures are taken every hour in 15 May-15 June period. In this calculation, it is assumed that comfort temperature is 26˚C and cooling system is working 5 days in one week, from the hour 7.00 to 17.00. It is assumed that space temperature is 30˚C in the rest hours of day and holidays. It is assumed that natural ventilation is used and every break time classrooms are ventilated by opening windows.

Base Case

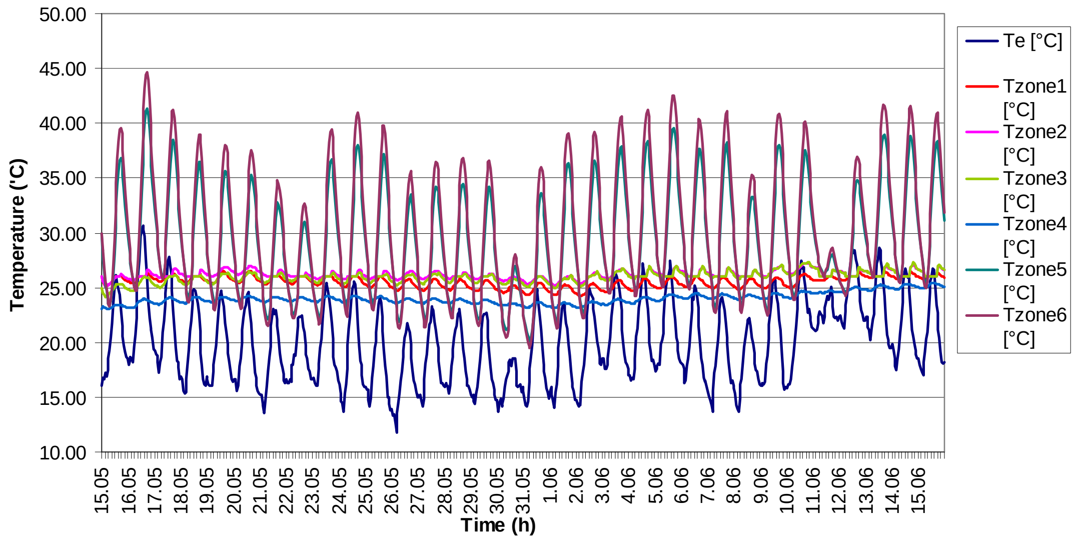

Figure 5.48: Temperature of zones for base case in 15 May-15 June (Antalya)

Window Renovation

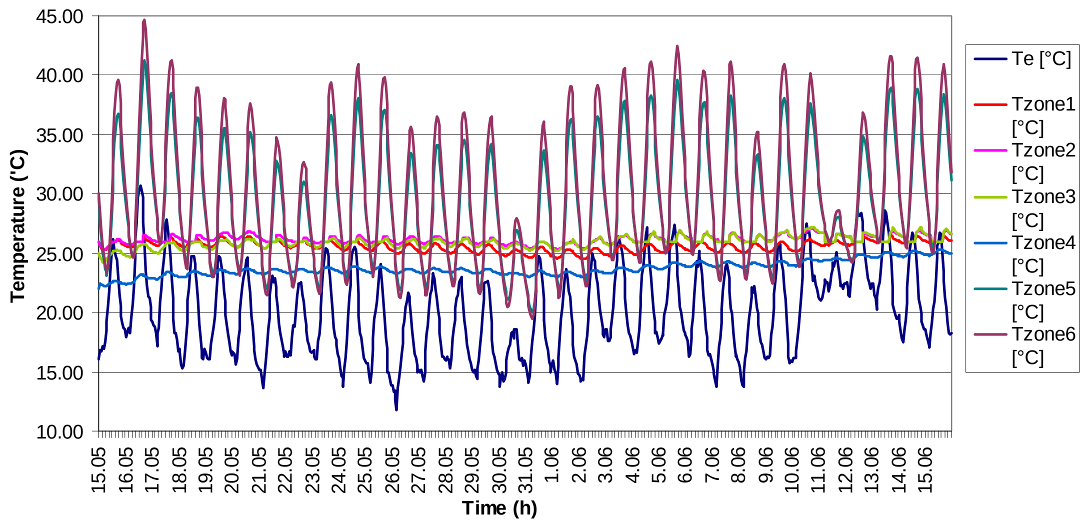

Figure 5.49: Temperature of zones for window renovation strategy in 15 May-15 June (Antalya)

Shading Devices

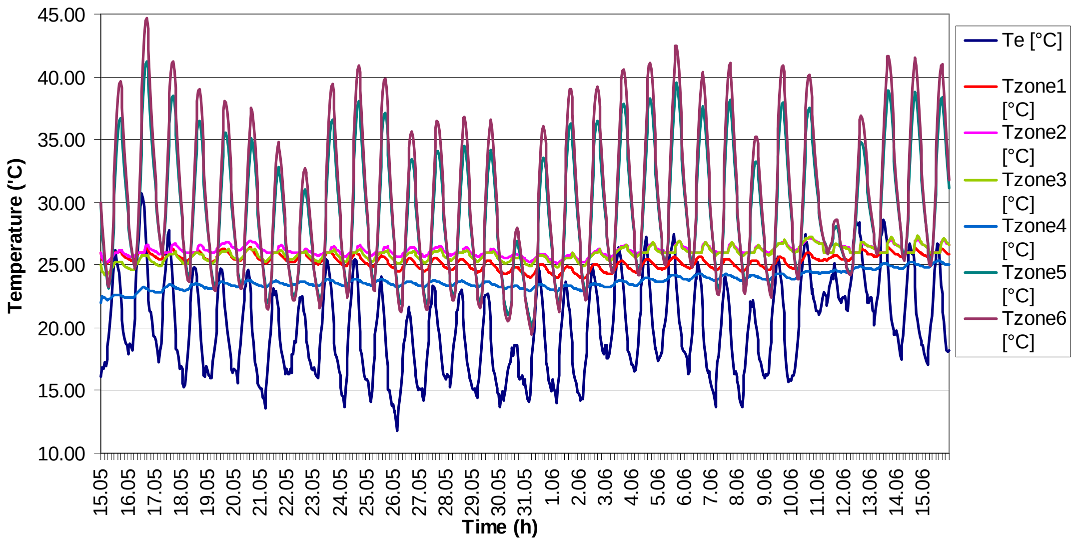

Figure 5.50: Temperatures of zones for shading devices in 15 May-15 June (Antalya)

Combined Strategy

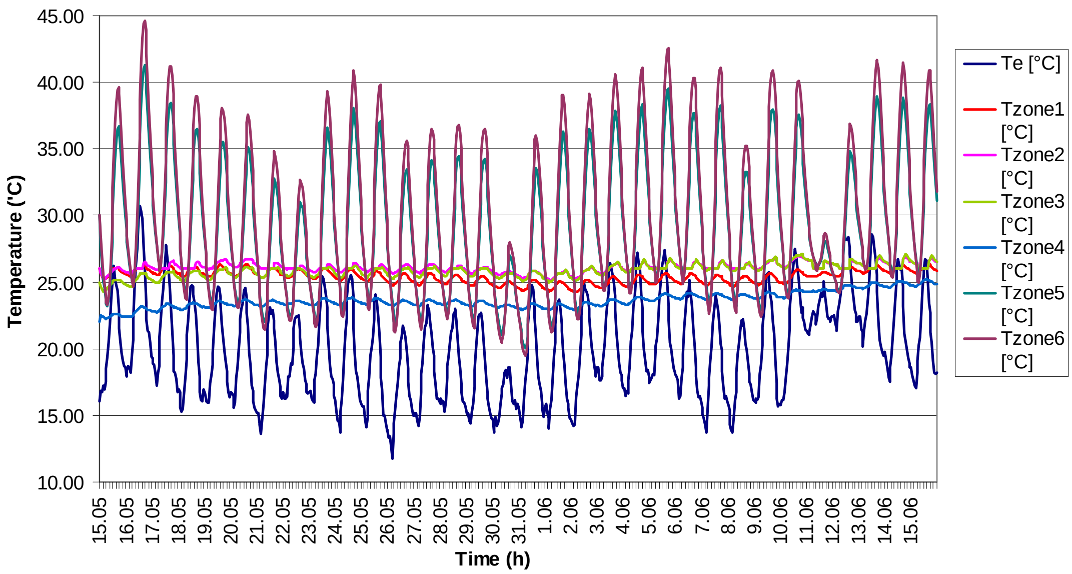

Figure 5.51: Temperatures of zones for combined strategy in 15 May-15 June (Antalya)

There is not so much differences between the average temperatures of zones as it is seen in Table 5.26.

Table 5.26: Average temperature of zones for base case, window renovation strategy, shading devices strategy and combined strategy in 15 May-15 June (Antalya)

Case Type	Cooling Season	T ambient	Zone1	Zone2	Zone3	Zone4	Zone5	Zone6
Base Case			25.49	26.16	25.94	24.01	29.37	30.27
Window Renovation	Average (‘C)	19.98	25.56	26.14	25.94	23.71	29.34	30.26
Shading Devices			25.28	26.13	25.85	23.71	29.32	30.26
Combined Strategy			25.39	26.08	25.85	23.64	29.32	30.25

With renovation strategies, cooling energy demand and cooling load are reduced. With combined strategy energy saving is % 67 in zone 1, % 40 in zone 2, and % 40 in zone 3. (Table 5.27) For zone 4 there is no cooling demand. Hourly cooling energy demand can be seen in Figure 5.52. Total energy savings for cooling period is % 42 with combined strategy. (Table 5.28)

Table 5.27: Cooling energy demand and cooling load of zones for base case, window renovation strategy, shading devices strategy and combined strategy in 15 May- 15 June (Antalya)

Thermal Zones	Case Type	Cooling Energy (kWh)	Cooling Load (kWh/m2)
	Base Case	434.9	0.09
Zone 1	Window Renovation	308.8	0.06
	Shading Devices	209.7	0.04
	Combined Strategy	169.7	0.03
	Base Case	695.2	0.30
Zone 2	Window Renovation	515.5	0.22
	Shading Devices	523.7	0.22
	Combined Strategy	417.7	0.18
	Base Case	838.0	0.23
Zone 3	Window Renovation	645.0	0.18
	Shading Devices	586.0	0.16
	Combined Strategy	501.0	0.14

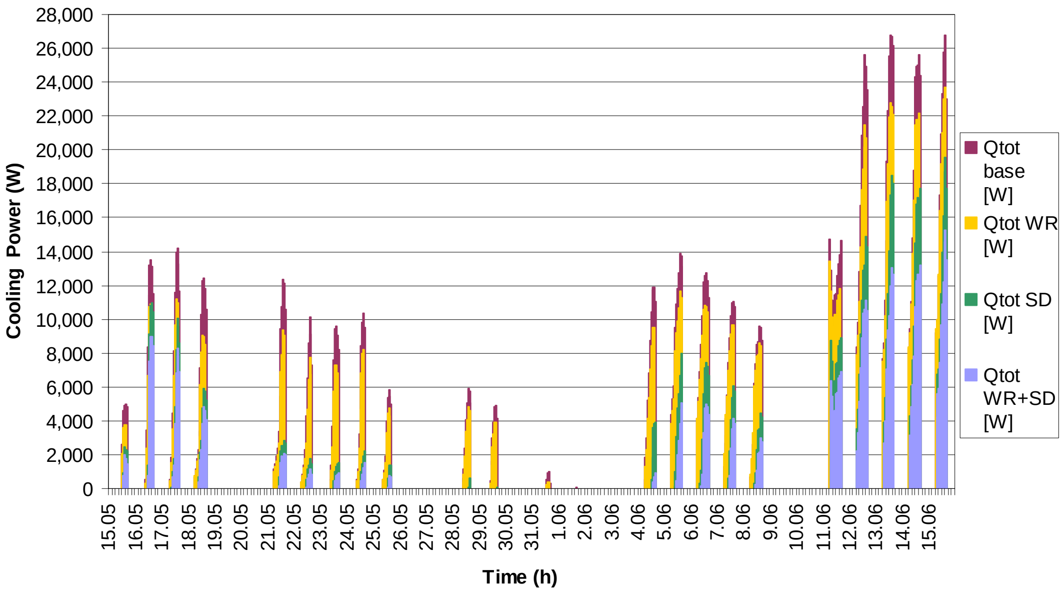

Figure 5.52: Hourly cooling power for each case in 15 May- 15 June (Antalya)

Table 5.28: Total cooling energy and cooling load in 15 May- 15 June (Antalya)

Case Type	Cooling Energy (kWh)	Cooling Load (kWh/m2)
Base Case	1968.1	0.12
With Window Renovation	1469.3	0.09
With Shading Devices	1319.0	0.08
Combined Strategy	1088.4	0.07

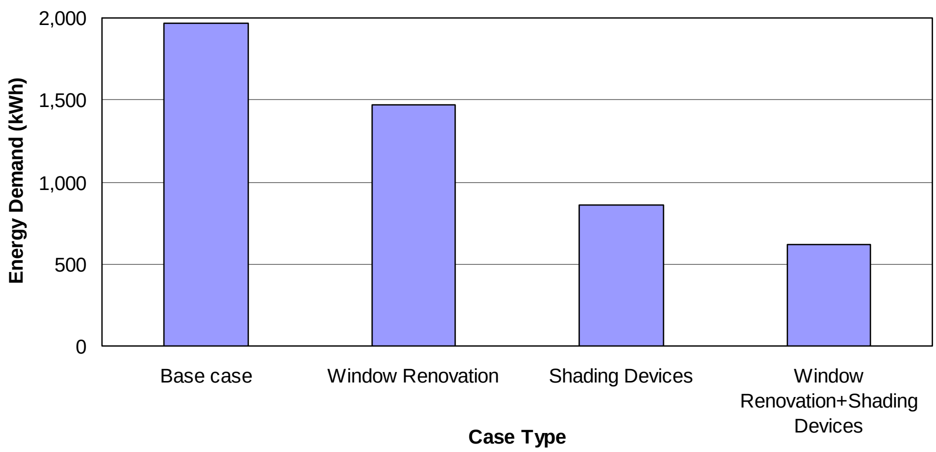

Figure 5.53: Total cooling demand in 15 May- 15 June (Antalya)

With combined strategy energy savings are high according to the base case as it is seen in Table 5.28.

Table 5.29: Annually total heating and cooling energy demand and load (Antalya)

Case Type	Heating Energy (kWh)	Heating Load (kWh/m2)	Cooling Energy (kWh)	Cooling Load (kWh/m2)	Total Energy (kWh)	Total Load (kWh/m2)
Base Case	8049.9	0.51 (100)	1968.1	0.12 (100)	10018.0	0.64 (100)
With Window Renovation	7401.0	0.47 (92)	1469.3	0.09 (75)	8870.3	0.57 (89)
With Shading Devices	-	-	1319.0	0.08 (66)	1319.0	0.08 (66) (SP)
Combined Strategy	-	-	1088.4	0.07 (58)	1088.4	0.07 (58) (SP)

Heating and cooling load for each case for heating and cooling seasons are seen in Table 5.29. In heating season energy demand is reduced with window renovation. In heating season with window renovation situation energy saving is %8. In cooling season with window renovation energy saving is %25. In annually calculation for heating season energy saving is %11 for window renovation. The energy savings with shading devices and combined strategy for annually calculations is equal only for the summer period because shading devices are not used in winter season period. When the shading devices are used only in cooling season (summer period) energy saving is %34 according to base case. When combined strategy is used in cooling season (summer period) energy saving is % 42. Total energy demand of building can be seen in Figure 5.53.

5.4.5. Hot-Dry Climate (Diyarbakır)

Characteristic city for hot-humid climate is Diyarbakır. For Diyarbakır both heating and cooling demand are investigated. Using window renovation for heating system and using window renovation, shading devices and using them together in cooling season are investigated.

5.4.5.1. Window Renovation

In existing project in all windows, window type which has an U-value 2.83 is used. For window renovation window type which has an U-value 1.24 is used. Optical properties of window are seen in Figure 5.10 and Figure 5.11.

5.4.5.2. Shading Devices

In existing building shading devices are not used. In suggested application, shading devices are used with shading factor 0.2. Occupancy hours are Monday to Friday, from 12.00 -16.00 pm. In heating period it is assumed that the shading devices are not working. Shading devices does not transfer sun light. In school especially for classroom light is so important for comfort conditions, for these reasons shading factor has been taken 0.2. Shading device properties can be seen in Figure 5.12.

5.4.5.3. Winter Period (January) Calculations and Results

In Figure 5.54 temperatures of zones for base case, in Figure 5.55 temperatures for window renovation are seen. In fact the school building has not a mechanical ventilation system for each cases including base case. In this study it is assumed that there is a mechanical ventilation system in building. It is effective especially in zone 1 in where classroom temperatures are not in comfortable conditions. The air is supplied with an air change rate 0.95 1/h. Operating hours for ventilation system is from 12.00 to 16.00 during the school days. Supply air temperature is adjusted as outside temperature.

Base Case

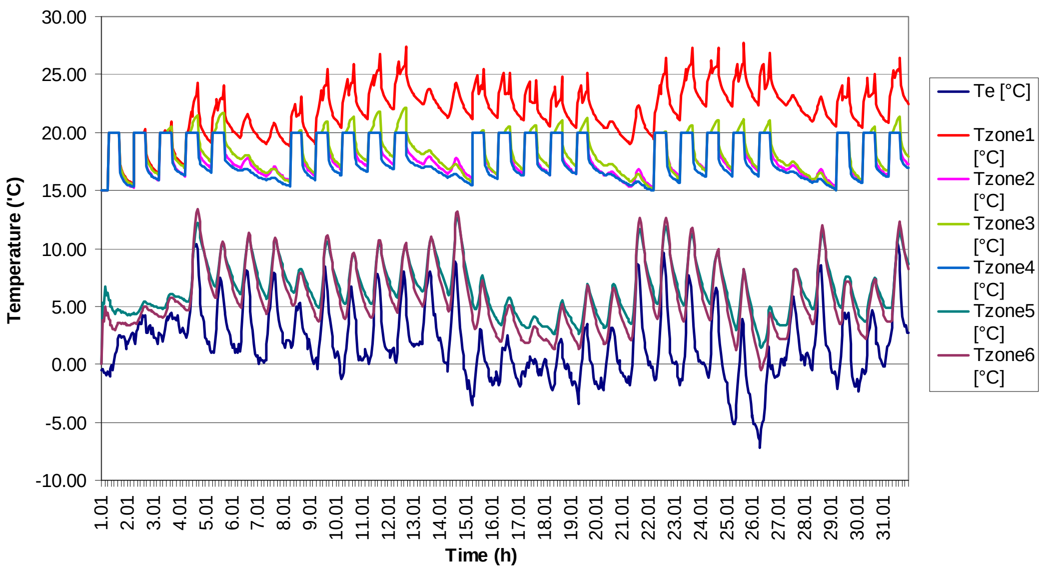

Figure 5.54: Temperatures of zones for base case in January (Diyarbakır)

It can be seen in Figure 5.56 temperatures of Zone 1 for window renovation strategy is higher then base case.

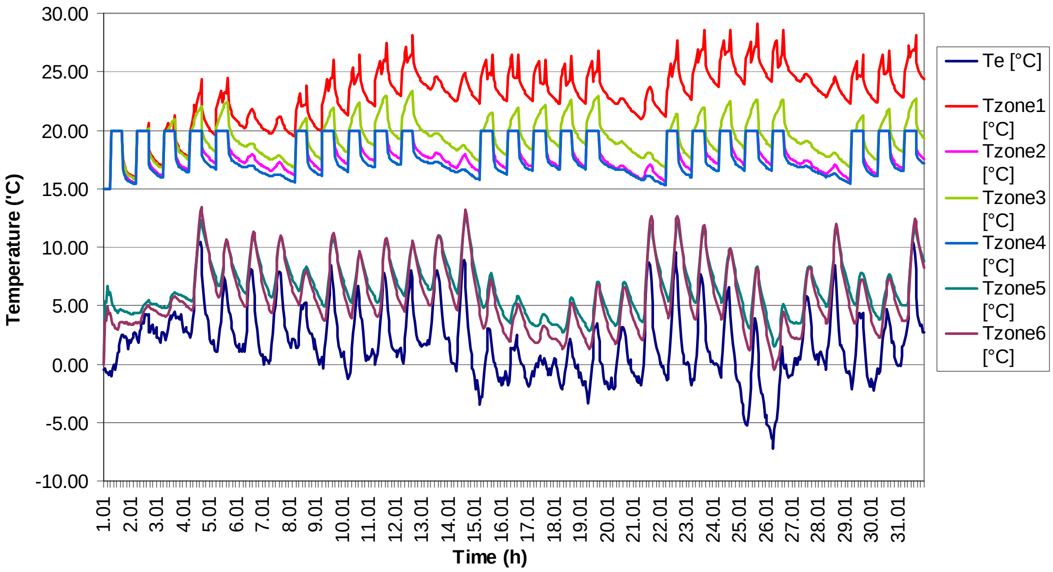

Figure 5.55: Temperatures of zones for window renovation in January (Diyarbakır)

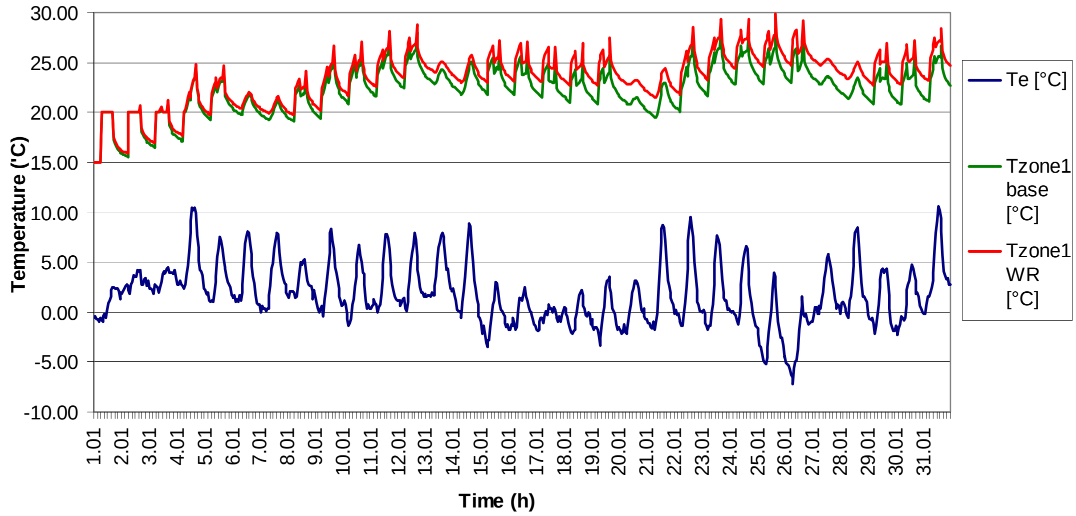

Figure 5.56: Temperatures of zone 1 for base case and window renovation strategy in January (Diyarbakır)

Table 5.30: Average temperatures of zones for base case and window renovation strategy in January (Diyarbakır)

Case Type	Heating Season	T ambient	Zone1	Zone2	Zone3	Zone4	Zone5	Zone6
Base Case	Average (˚C)	1.77	21.90	17.91	18.27	17.63	6.47	5.75
Window Renovation			23.30	18.09	19.40	17.78	6.56	5.77

Average temperatures of zones are not so different from each other. (Table 5.30) Using renovation strategies are effective in heating demand and heating load as it is seen in Table 5.31.

Table 5.31: Total heating demand and heating load of zones for base case and window renovation strategy in January (Diyarbakır)

Thermal Zones	Case Type	Heating Energy (kWh)	Heating Load (kWh/m2)
Zone 1	Base case	745.0	0.16
	Window renovation	591.6	0.13
Zone 2	Base case	3798.9	1.65
	Window renovation	3379.0	1.47
Zone 3	Base case	1412.1	0.40
	Window renovation	510.2	0.14
Zone 4	Base case	13111.0	2.53
	Window renovation	12365.8	2.39

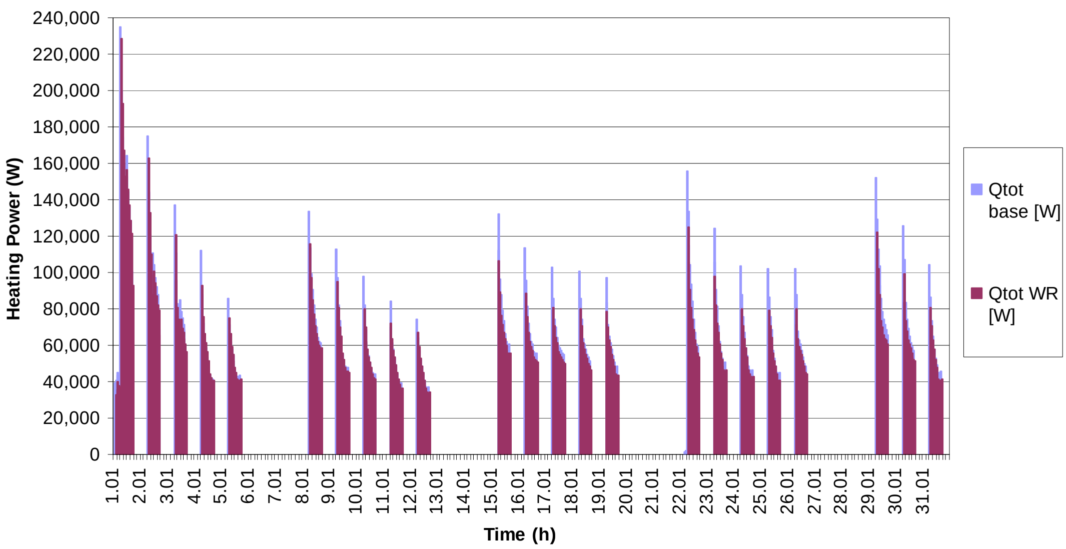

Figure 5.57: Hourly heating power for each case in January (Diyarbakır)

Hourly heating power of window renovation strategy is less then base case. (Figure 5.57) With window renovation energy savings of total heating load is % 12 as it is seen in Table 5.32.

Table 5.32: Total heating energy and heating load in January (Diyarbakır)

	Base Case	Window Renovation
Heating Energy (kWh)	19067.0	16846.7
Heating Load (kWh/m2)	1.22	1.08

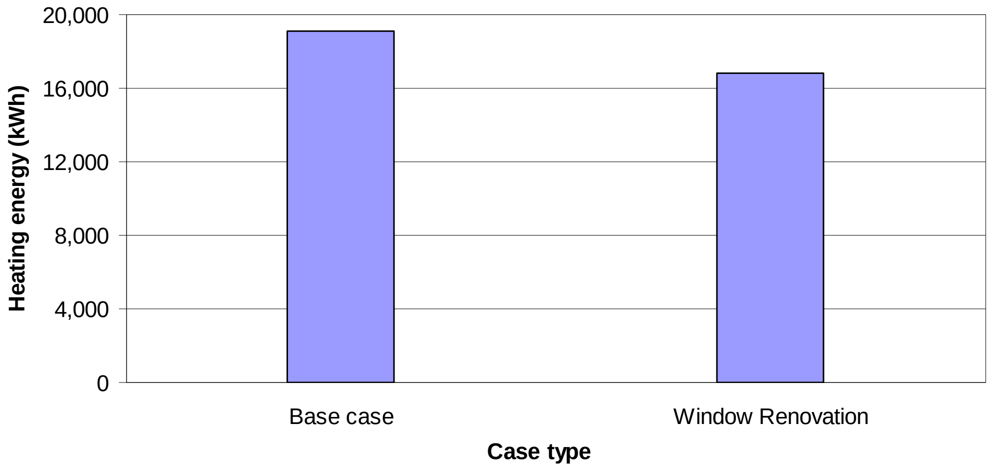

Figure 5.58: Total heating energy for each case in January (Diyarbakır)

Total heating energy of zones can be seen in Figure 5.58. Using window renovation strategy heating energy demand is reduced 2220.3 kWh according to the base case.

5.4.5.4. Summer Period (15 May-15 June) Calculations and Results

Temperatures of zones for base case, window renovation strategy, shading devices strategy and combined strategy are calculated. (Figure 5.59, Figure 5.60, Figure 5.61, Figure 5.62) Cooling energy demand for each zones and total energy demand for building are calculated. Temperatures are taken every hour in 15 May-15 June period. In this calculation, it is assumed that comfort temperature is 26˚C and cooling system is working 5 days in one week, from the hour 7.00 to 17.00. It is assumed that space temperature is 30˚C in the rest hours of day and holidays. It is assumed that natural ventilation is used and every break time classrooms are ventilated by opening windows.

Base Case

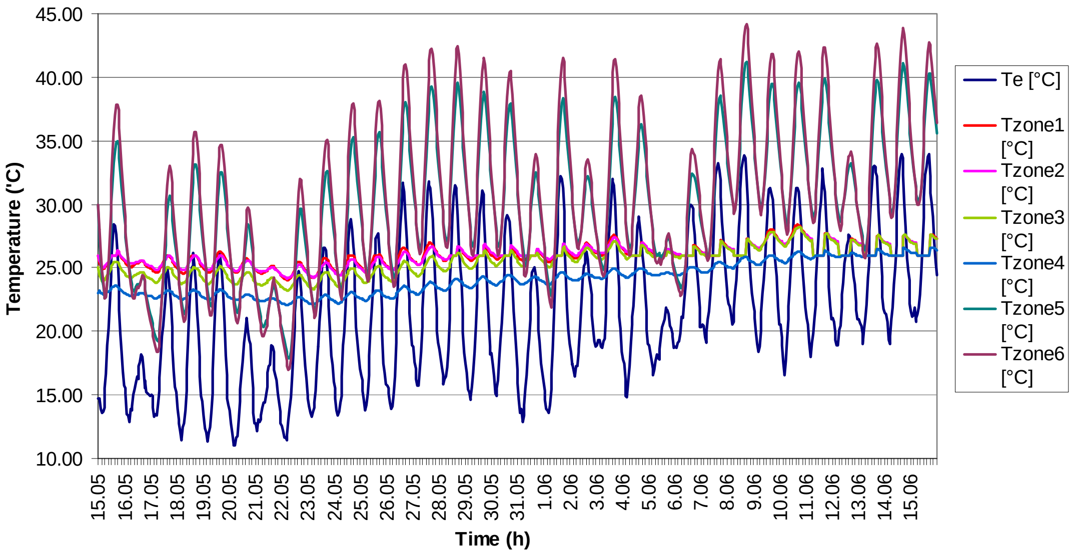

Figure 5.59: Temperatures of zones for base case in 15 May – 15 June (Diyarbakır)

Window Renovation

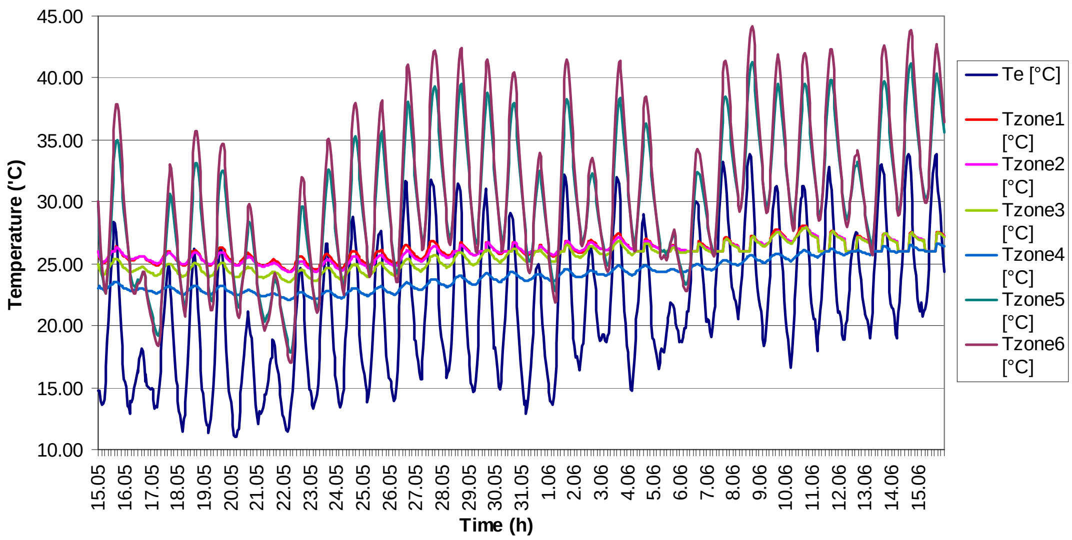

Figure 5.60: Temperatures of zones for window renovation strategy in 15 May – 15 June (Diyarbakır)

In Zone 5 and Zone 6 there is not cooling system. Temperatures of these zones are nearly 45 ˚C in some periods as it is seen in figures.

Shading Devices

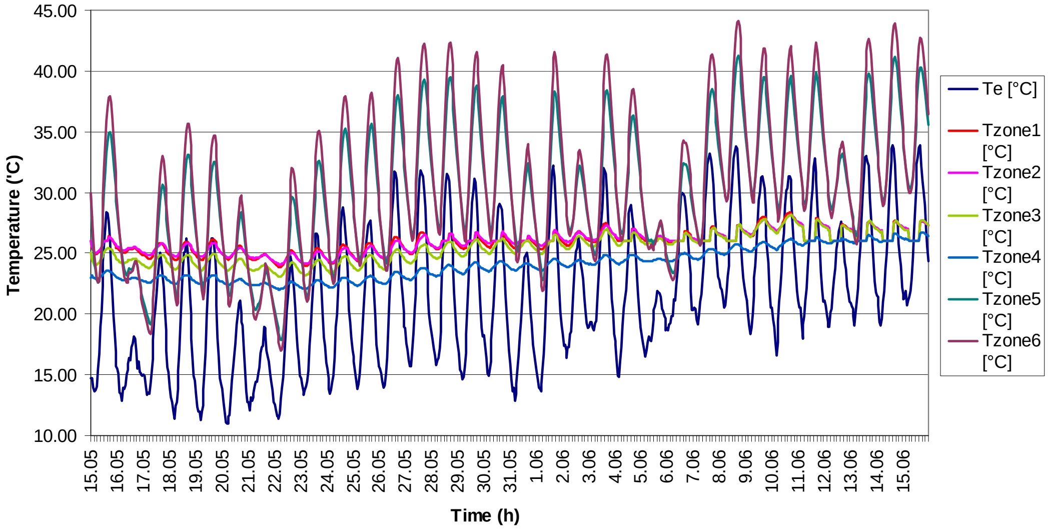

Figure 5.61: Temperatures of zones for shading devices in 15 May – 15 June (Diyarbakır)

Combined Strategy

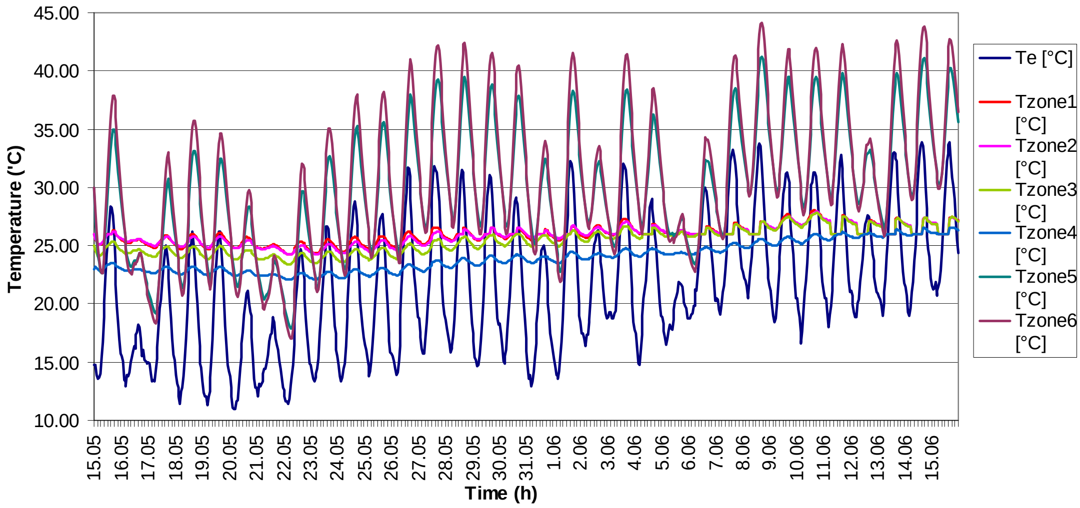

Figure 5.62: Temperatures of zones for combined strategy in 15 May – 15 June (Diyarbakır)

Average temperatures of zones are not so different from each other as it is seen in Table 5.33

Table 5.33: Average temperature of zones for base case, window renovation strategy, shading devices strategy and combined strategy in 15 May-15 June (Diyarbakır)

Case Type	Cooling Season	T ambient	Zone1	Zone2	Zone3	Zone4	Zone5	Zone6
Base Case	Average (˚C)		25.97	25.96	25.48	24.09	29.96	30.73
Window Renovation	Average (˚C)		26.04	25.96	25.51	24.03	29.96	30.72
Shading Devices	Average (˚C)	21.44	25.88	25.91	25.40	24.03	29.95	30.72
Combined Strategy	Average (˚C)		25.86	25.39	23.97	23.74	29.94	30.71

With renovation strategies cooling energy demand and cooling load are reduced. With combined strategy energy saving is % 35 in zone 1, % 36 in zone 2, % 37 in zone 3, %60 in zone 4 (Table 5.34). Hourly cooling energy demand can be seen in Figure 5.63. Total energy savings for cooling period is % 36 with combined strategy. (Table 5.35) Energy savings with combined strategy is maximum as it is seen in Figure 5.64.

Table 5.34: Cooling energy demand and cooling load for base case, window renovation strategy, shading devices strategy and combined strategy 15 May- 15 June (Diyarbakır)

Thermal Zones	Case Type	Cooling Energy (kWh)	Cooling Load (kWh/m2)
	Base Case	2084.2	0.46
Zone 1	Window Renovation	1687.3	0.37
	Shading Devices	1611.1	0.35
	Combined Strategy	1395.7	0.30
	Base Case	899.4	0.39
Zone 2	Window Renovation	689.4	0.30
	Shading Devices	726.7	0.31
	Combined Strategy	594.6	0.25
	Base Case	1176.9	0.33
Zone 3	Window Renovation	895.1	0.25
	Shading Devices	944.5	0.26
	Combined Strategy	744.1	0.21
	Base Case	273.2	0.05
Zone 4	Window Renovation	172.9	0.03
	Shading Devices	215.6	0.04
	Combined Strategy	142.6	0.02

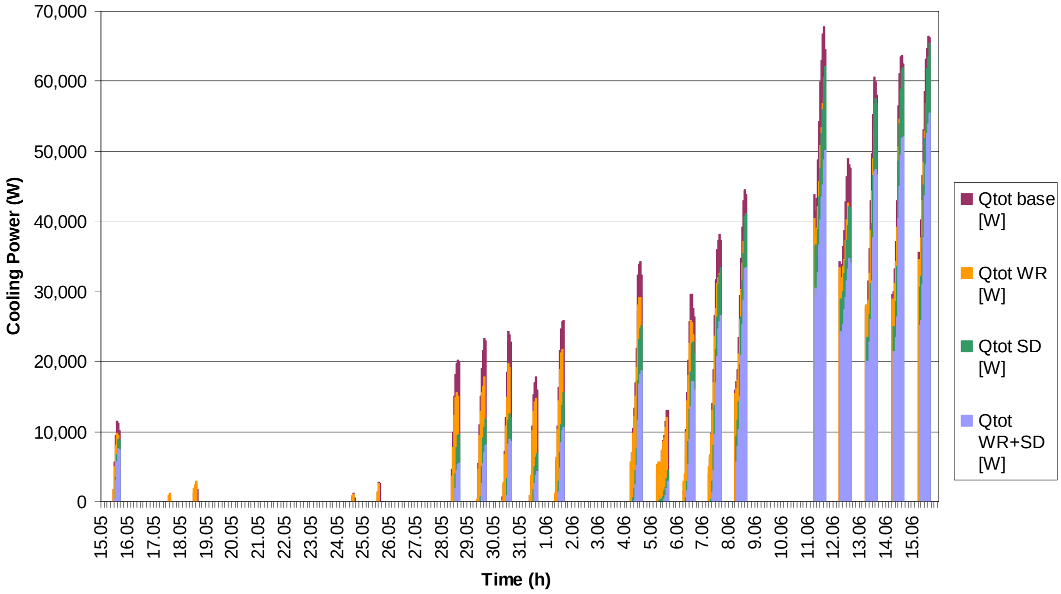

Figure 5.63: Hourly cooling power for each case in 15 May- 15 June (Diyarbakır)

Table 5.35: Total cooling energy demand and cooling load in 15 May- 15 June (Diyarbakır)

Case Type	Cooling Energy (kWh)	Cooling Load (kWh/m2)
Base Case	4433.7	0.28
Window Renovation	3444.7	0.22
Shading Devices	3497.9	0.22
Combined Strategy	2907.0	0.18

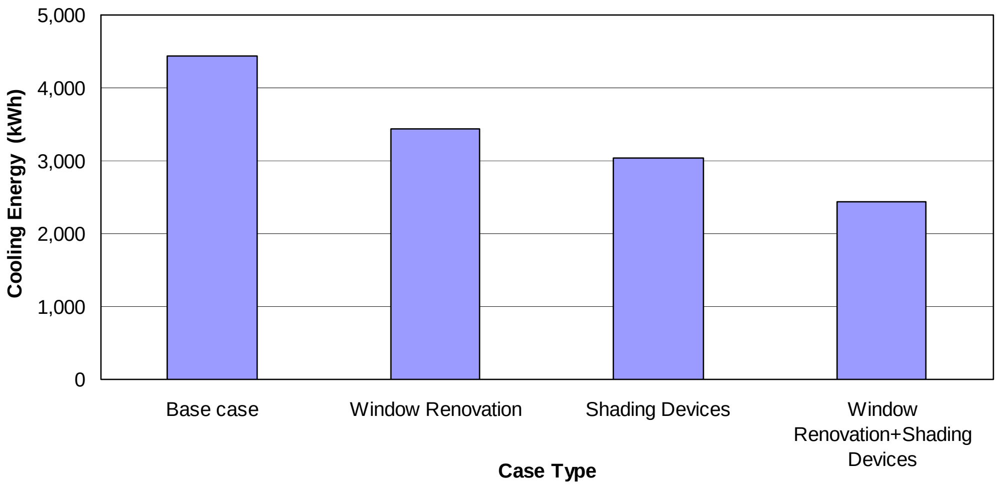

Figure 5.64: Total cooling energy demand in 15 May- 15 June (Diyarbakır)

Table 5.36: Annually total energy demand and energy load (Diyarbakır)

Case Type	Heating Energy (kWh)	Heating Load (kWh/m2)	Cooling Energy (kWh)	Cooling Load (kWh/m2)	Total Energy (kWh)	Total Load (kWh/m2)
Base Case	19067.0	1.22 (100)	4433.7	0.28 (100)	23500.7	1.51 (100)
Window Renovation	16846.7	1.08 (88.5)	3444.7	0.22 (78)	20291.4	1.30 (86)
Shading Devices	-	-	3497.9	0.22 (78)	3497.9	0.22 (SP) (78)
Combined Strategy	-	-	2907.0	0.18 (64)	2907.0	0.18 (SP) (64)

Heating and cooling load for each cases for heating and cooling seasons are seen in Table 5.36. In heating season energy demand is reduced with window renovation. In heating season with window renovation strategy, energy saving is %12.5. In cooling season with window renovation energy saving is %22. In annually calculation for energy saving is %14 for window renovation. The energy saving with shading devices and combined strategy for annually calculations is equal only for the summer period because shading devices are not used in winter season period. When the shading devices are used only in cooling season (summer period) energy saving is %22 according to base case. When combined strategy is used in cooling season (summer period) energy saving is % 36. Total energy demand of building can be seen in Figure 5.64.

These renovations, window renovation, increasing insulation thickness renovation, using shading devices are renovations that are made in building envelope. Besides these renovations active system are also important for to get energy saving. In the following study electrical consumption of a school building is investigated.

5.4.6. Active System Strategies for Scharnhauserpark School in Stuttgart

In this study electrical energy consumption of a school building in Stuttgart investigated. Users behaviors are important in this study. In this part, strategies for usage time of electrical equipments in schools are investigated and it is seen that energy demand will be reduced with very basic methods.

5.4.6.1. Scharnhauserpark Project and School Building

Scharnhauserpark Project (Figure 5.66) is designed as an exemplary ecological community development, where low energy building standards are prescribed for all plots and a wood-fired ORC co-generation plant will deliver electricity and heating energy. Combining work places, residential areas and green park sections leads to an integrated living and transportation concept with high comfort and low energy consumption. The whole investment volume of the project with 480,700 m2 built floor area is 1.5 billion Euros. [21]

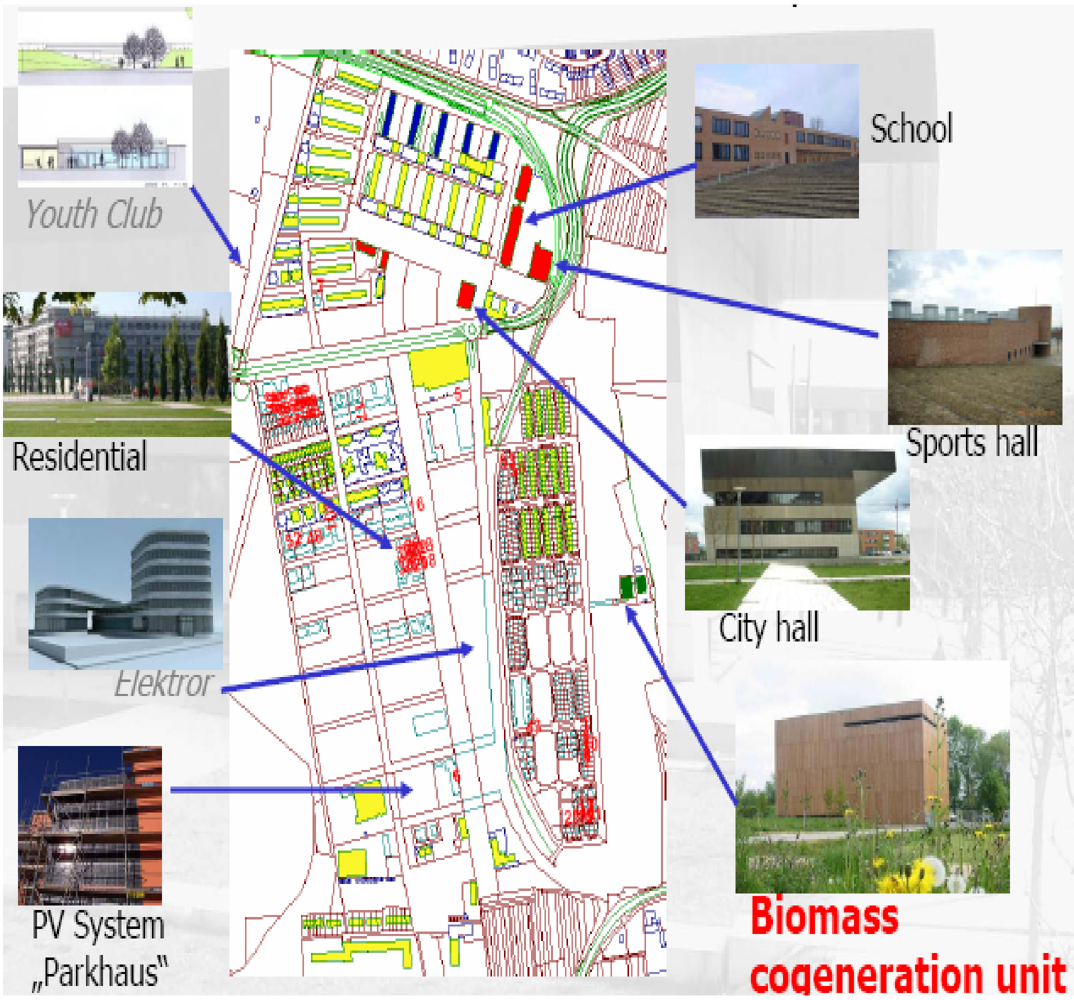

Figure 5.65: Scharnhauserpark Project

In this part of study electrical energy consumption of school building is investigated.

School and Gymnasium:

The school and gymnasium are part of a new town, which is currently being developed on the grounds of an old barracks area. The site forms the edge of the city facing the northeast.

The rounded form of the sports hall will mark the edge of the urban development. Facing the other side, the school building fits into the right-angled structure of the existing barracks. Both plan and section have been conceived to support the strong character of the street space. [22]

Inside the building, the rectangular streets are transformed into corridors and the residential buildings into classrooms. While the interior and exterior walls of the school house are characterized by crude brick stones, the atmosphere of the classrooms is dominated by wood. [22] On the roof of the sports hall there is a little sports ground that is illuminated in the evening by the cylindric shaped glass block walls on top of the hall. Between sports hall and school building lies the playground for the students. Its spatial setting and individuality compliments the plastic form of the west side of the sports hall, so too the prominent free-standing stairs, which slope towards the south. From there one has a beautiful view over the city and the distant landscape.[22]

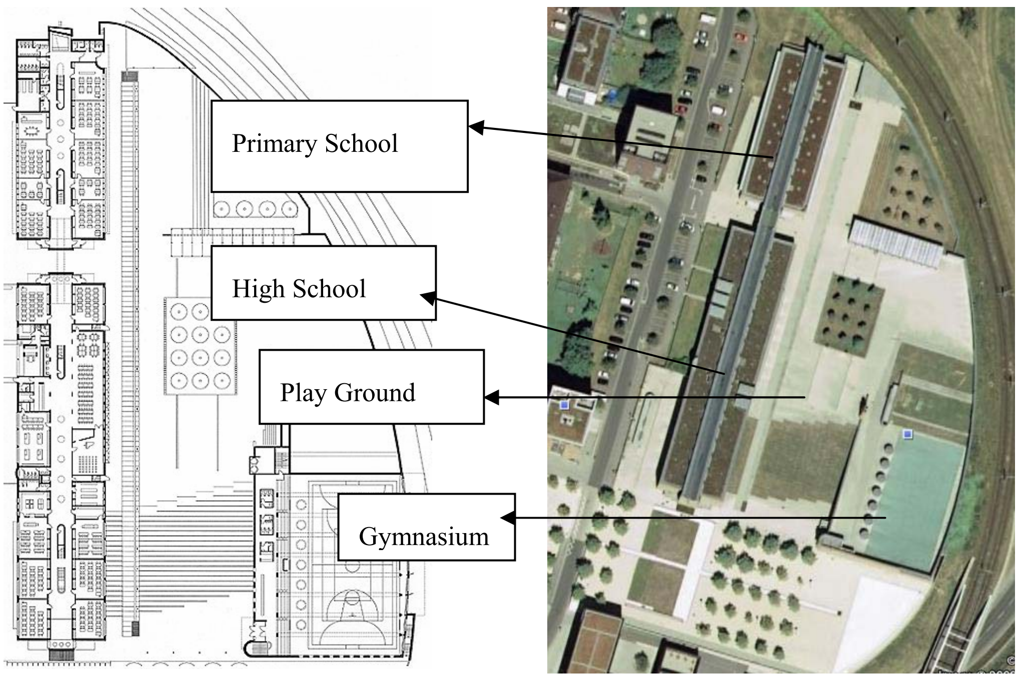

Figure 5.66: Site plan and view of school building [22, 23]

Plan of primary school building, high school building and some inside views are seen in Figure 5.67 and Figure 5.68.

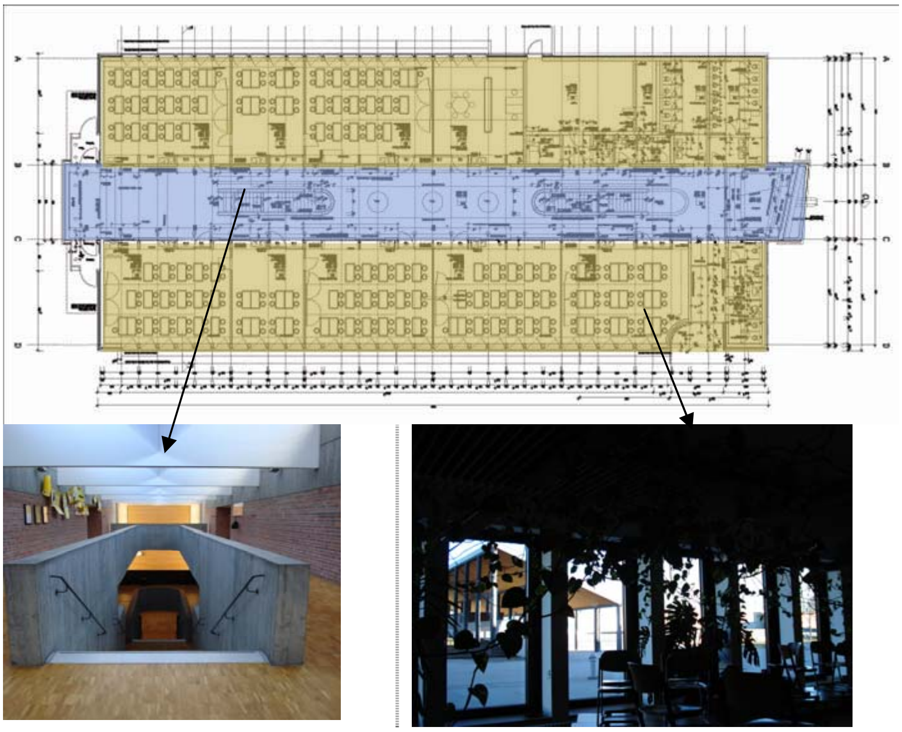

Figure 5.67: Plan and view of school building [22, 23]

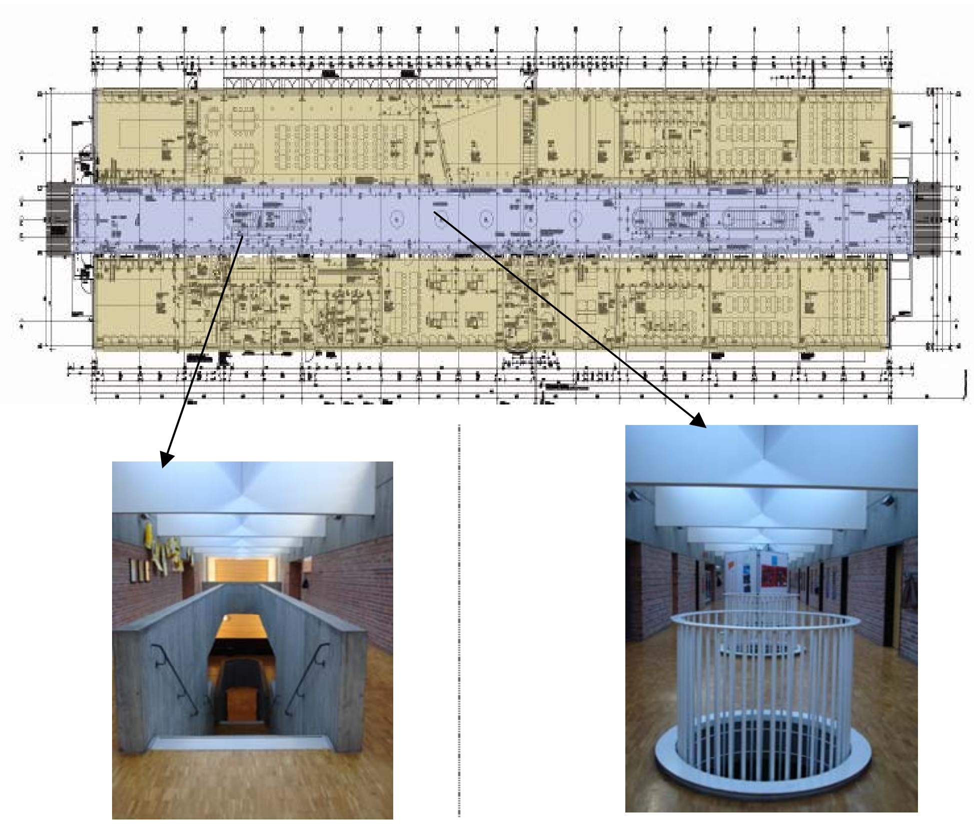

Figure 5.68: Plan and inside views of high school building

Wiews of school from outside can be seen in Figure 5.69.


Figure 5.69: Views from high school building

In Figure 5.70 upper corridor and connection between the primary school building and high school building can be seen. Primary school building and high school buildings are connected to each other with a bridge.

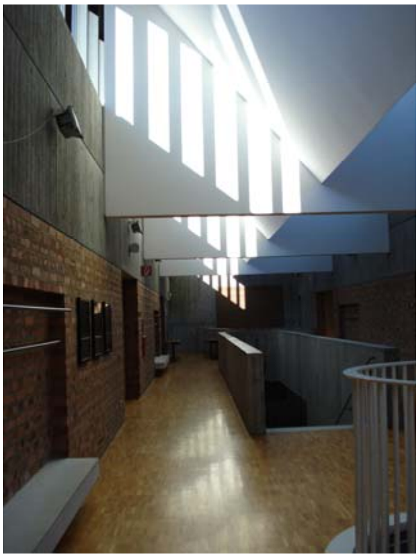


Figure 5.70: Upper corridor, and connection between primary school and high school.

5.4.6.2. Electrical Energy Calculation

In this study electrical energy demand of school building investigated. For this calculation, electrical equipments and their usage time in all rooms are determined. (Classrooms, teachers' room, kitchen etc) Then power of every equipment is calculated with an instrument called Energy Monitor 3000 for when they are on, when they are stand-by.(Figure 5.71)

Figure 5.71: Instrument used for power calculation

Electrical Energy Calculation

Electrical energy calculation steps are determining the school days and holidays, determining the electrical equipments and their consumptions, grouping the electrical equipments calculations, determining energy savings.

Determining the School Days and Holidays

For beginning to the calculation, school days and holidays in Stuttgart are determined.

Christmas: 3 weeks = 15 day

Winter(February): 1 week = 5 days

Easter: 2 weeks =10 days

Pentecost: 1 week =5 days

Summer: 6,5 weeks =32 days

Autumn: 1 week =5 days

52 weekends =104 days

Extra fest days= 4 days

Total: 180 days of holidays

365–180 = 185 days of school

In summer holiday every electrical equipment are off. They are not working.

Determining the Electrical Equipments and their Consumptions

Secondly all electrical equipment are determined class by class and room by room. Their power are calculated. (Table 5.37)

Table 5.37: Electrical energy calculation

Room Number	Room name	Consumption Group	Electrical Equipment	Unit	Electric Power on	std-by	Occupation Time	Not-Occupation Time	Consumption kWh on	std-by
	Floor	Lighting	Lamp 11W	32	11.00		990		348.00	
2.51	Class	Lighting	Lamp 36W	14	72.00		925		932.00	
2.51	Class	Lighting	Lamp 26W	2	52.00		925		96.00	
2.51	Class	Studying	Tape	1	6.00	4.5	185	7,807		
2.52	Class	Lighting	Lamp 36W	14	72.00		925		932.00	
2.52	Class	Lighting	Lamp 26W	2	52.00		925		96.00	
2.52	Class	Studying	Tape	1	11.00	5.5	185	7,807		
2.52	Class	Studying	Overhead-Projector	1	450.00		185		83.00	
2.52	Class	Kitchen	Kettle	1	965.00		15		15.00	
2.53	Courseroom	Lighting	Lamp 36W	9	72.00		555		360.00	
2.53	Courseroom	Studying	Computer	1	78.00	12	370	7,622	28.80	91.00
2.53	Courseroom	Studying	PC	1	74.00	8	370	7,622	27.30	61.00
2.53	Courseroom	Studying	Screen	1	4.00	4	370	7,622	1.40	30.40
2.53	Courseroom	Studying	Overhead-Projector	1	450.00		185		83.00	
2.53	Courseroom	Studying	Printer	1	14.00	4.5	15	7,977	0.60	143.00
2.54	Courseroom	Lighting	Lamp 36W	9	72.00		555		360.00	
2.55	Class	Lighting	Lamp 36W	14	72.00		925		932.00	
2.55	Class	Lighting	Lamp 26W	2	52.00		925		96.00	

In this list, room numbers, room names, consumption type of electrical instruments, name and units of electrical instruments are determined. Then electric power usage of instruments when they are on and when they are stand-by are calculated. Occupation and not-occupation times of electrical equipments are determined according to the school days and holidays. Lastly total energy consumption of instruments is calculated for when they are on and stand-by mode according to their usage time.

Same calculations are done for primary school building and garden. Because in garden electricity is also used for outside lighting.

Grouping the Electrical Equipments

After all these calculations, these energy consumptions are determined in three groups:

- Study equipment
- Kitchen
- Lighting

Study equipment

Computers

Number of school days are 185. It is assumed that computers are using 2 hours per day.

185*2 =370 hours

In summer holiday everything is off. It is 32 days

365-32 =333 days

333*24 =7992 hours

370 hours computers are on.

7992 -370 = 7622 hours computers are stand–by

When computers are on total electrical consumption is 28.80 kWh, when computers are stand-by total electrical consumption is 91.00 kWh.(Table 5.37) As it is seen electrical consumption of computers when they are stand-by is higher then when they are on. Because the computers are on in 370 hours and they are stand-by in 7622 hours.

All of the occupation and not occupation hours have been calculated for other other equipments of kitchen and lighting.These results have been multiplied with electric power of that insruments fort o get energy consumption. Usage time of equipments' imformations have been taken from the person who is responsible for the school and people who are working in kitchen. Firstly occupation and non-occupation hours are calculated for equipments.

Technical Room Electrical Equipments

Oven: it is used 15 times a year.

Every times it is used 2-3 hours

15*3 =45 hours.

Kitchen

Washing-up Machine: it is used everyday 3 hours. 3*185 = 555 hours.

Oven : it is used everyday 1,5 hour. 1,5 *185 = 278 hours

Cooling Device : It is on Monday to Thursday from Monday morning at 07.00 to Thursday afternoon 14.00.

24*3 =72

72+7 =79 hours it is on one week.

185 school days

185/5 =37 weeks.

37*80 = 2960 hours.

Lighting

Lighting for Corridors High School Ground Floor

School day is 185 days. It is assumed that 95 days in winter and 90 days in summer Ground floor lighting can be seen in Figure 5.72. For ground and first floor in winter time lights are on Monday to Friday from 06.45 to 18.00.

95* 11= 1045 hours

In summer time lights are on Monday to Friday from 06.55 to 08.00 and from 17.00 to 19.00

90*3 = 270 hours, Total =1045 +270 =1315 hours

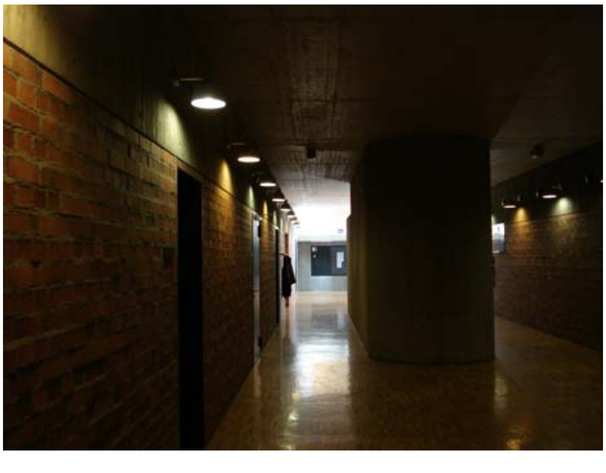

Figure 5.72: Ground floor lighting

Lighting for Corridors of High School Second Floor

School day is 185 days. It is assumed that 95 days in winter and 90 days in summer.

For Second floor in summer and winter time lights are on from 07.00 to 09.00 and from 17.00-20.00 . 185 *5 = 925 hours

Two kinds of lamps are used in second floor

Figure 5.73: Lamp types used in corridor

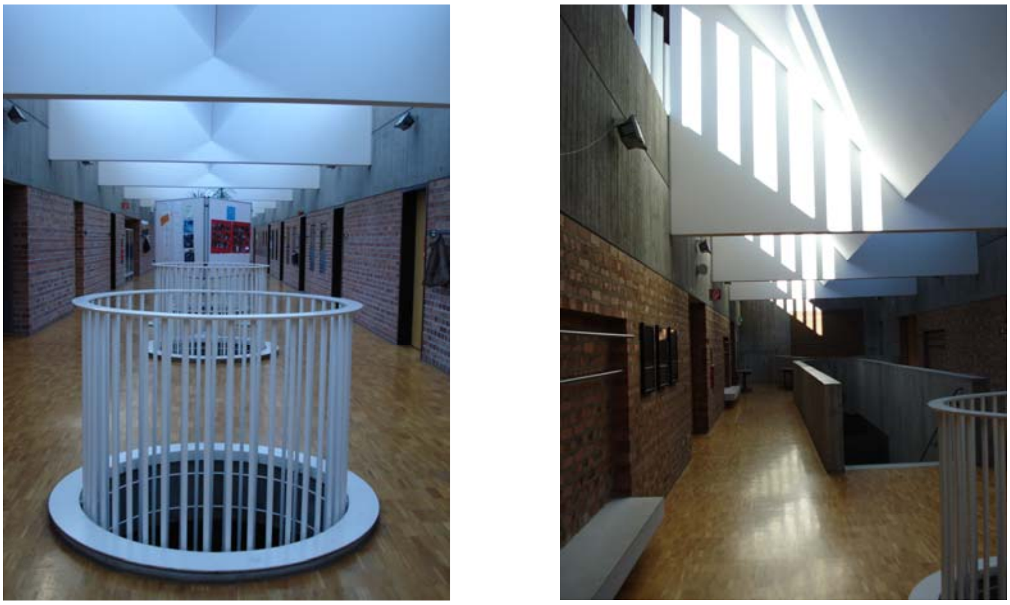

Figure 5.74: Views from inside

As a result of roof construction design which allows sun light to come in corridors, in third floor corridor lighting is not using during day except cloudy days. In Figure 5.74 lamp types used in corridors are seen.

Lighting for Entrance

In summer and winter time lighting is on Monday to Friday from 07.30 to 08.30 and from 16.30 to 19.00.

185 *3,5 = 648 hours.

Lamps that are used lighting for entrance can be seen in Figure 5.75.

Figure 5.75: Entrance lighting and lamp type

Outside and Garden Lighting

Outside:

School day is 185 days. It is assumed that 95 days in winter and 90 days in summer.

In winter time from 17.00 to 23.00 outside lighting is on.

6*95 =570 hours

In summer from 20.00 to 23.00 outside lighting is on.

3* 90 = 270 hours

Total

570+270 = 840 hours.

Garden:

School day is 185 days. It is assumed that 95 days in winter and 90 days in summer. In winter time from 17.00 to 23.00 garden lighting is on.

6*95 =570 hours

In summer from 20.00 to 23.00 garden lighting is on.

3* 90 = 270 hours

Total: 570+270 = 840 hours.

Outside and garden lighting are seen in Figure 5.76 and Figure 5.77.

Figure 5.76: Outside lighting

Figure 5.77: Outside and garden lighting

Table 5.38: Electrical energy consumption of groups in high school

	Energy Consumption (kWh)	
	On	Stand-by
Study	3920.25	5294.00
Kitchen	14027.00	769.00
Lighting	34436.00	-
Outside Lighting	1718.00	-

As it is seen in Table 5.38 study equipments need much more energy when they are stand-by according to the situation when they are on. This is because of the difference between the occupation and non-occupation hours. Non –occupation hours are more than occupation hours, that is why if the electrical equipments are left stand by mode, electrical consumption is more than the situation when they are on.

After grouping all the electrical equipments, total electrical demand (on +stand-by mode) is calculated for each group.(Table 5.39)

Table 5.39: Total electrical energy demand of groups in high school

High School Consumption	Electrical Energy Demand (kWh)
Study	9214.25
Kitchen	14796.00
Lighting	34436.00
Outside Lighting	1718.00
Total	60164.25

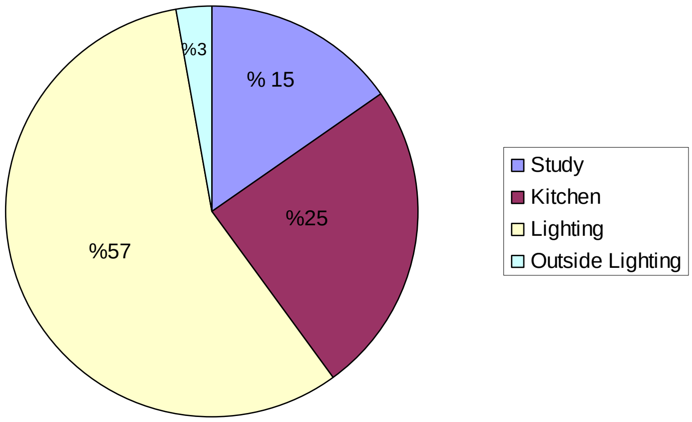

Figure 5.78: Percentage of electrical energy consumption groups for high school

In Table 5.39 total electrical energy consumption is shown and in Figure 5.78, percentage of groups consumption in high school is seen. As it is seen lighting has the most important part in this consumption. Secondly kitchen and then study equipments. For kitchen electrical energy consumption stand-by mode is not important as on mode. Like ovens, washing machines, fridges use so much energy when they are working. But for study equipments, reducing stand-by mode occupation hours causes benefits on total electrical energy consumption.

Table 5.40: Electrical energy demand when the study equipments are on and stand-by mode

	Electrical Energy Demand (kWh)
Study (on)	3920.25
Study (stand-by)	5294.00

In Table 5.40 it is seen that electrical consumption is high then on mode when the equipments are left stand-by mode. Percentage of stand by-mode is%58 when the percentage of on mode is %42.(Figure 5.79)

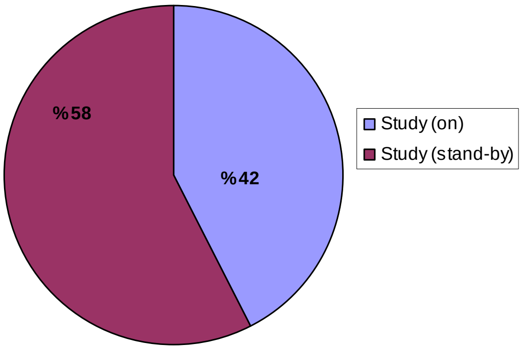

Figure 5.79: Percentage of electrical energy consumption of study equipments when they are on and stand-by

Energy Savings

For energy, saving it can be recommended switching of all electrical equipment when they are not using. With this very basic method, so much energy and money can be saved. For lighting it can be recommended not to use so much lamps at corridors especially corridors that are not used so much. These lamps can be arranged one is on and one is off to reduce the electricity bill.

Computers

All the PC's are seems-out and screens are stand-by at weekends.

46 weekends =92 days

PC

9*92*24 = 19 kWh (electric power, number of days and hours of one day are multiplied to get total energy))

Screen

5*92*24 = 11 kWh

Total =30 kWh

It can be saved 30 kWh by switching off the all the computers at weekends.

Here electricity cost for one kWh is taken 0.15 € and 40 is factor number.

It can be saved 30*40*0.15 = 180 € every year.

Lighting in High School

We can reduce the number of lights in first floor corridor because this corridor is not used so much. It has 2 classroom and other parts occured technical rooms and an office for person who is resposible for the school.

Lamps will be one on and one off. That time we do not use 12 lamps. One lamp use 11 kWh for one year. This means it can be saved;

11*12 =132 kWh per year.

Here electricity cost for one kWh is 0.15 € and factor number is 40.

We can save 132*40*0.15 = 792 € every year.

Total electrical energy savings can be reduced with taking very basic measures. For instance in this case study with switching off all computers at weekends and reducing number of some lamps in ground corridor it can be saved 972 € in one year. This kind of measures can also be taken in Turkey. Besides the renovation strategies in building envelope with this basic methods electrical energy consumption can be reduced and energy savings will be higher.

6. RESULTS OF CASE STUDY

In this part total energy savings and costs are calculated. Firstly number of schools in characteristic cities is defined. Then energy saving and saving costs for one school for heating season (January) and cooling season (15 May- 15 June) are calculated. Lastly how much energy and money will be saved is calculated.

6.1. Energy Saving Through Proposal Renovation Strategies

Firstly number of schools in characteristic cities for climate zones are defined then total energy saving are calculated for heating season. (Table 6.1, Table 6.2)

Table 6.1: Number of schools in cities which represent different climate zones [25]

Cities	Ankara	Antalya	Diyarbakır	Erzurum	İstanbul
Number of Schools	1300	1069	1183	1180	1420

Energy demand and savings of school building in heating season is seen in Table 6.2, in Table 6.3 energy demand and savings of school building for cooling season is seen

Table 6.2: Energy demand and savings of school building in heating season

Cities	Case Type	Energy Demand (kWh)	Energy Savings (kWh)	Heating Load (kwh/m2)	Heating Load Saving (kWh/m2)
İstanbul	Base Case	14638.5		0.94	0.10
	Window Renovation	13034.5	1604.0	0.84	(11%)
Erzurum	Base Case	32790.2	8298.0	2.11	0.54
	Combined Strategy (WR+IIT)	24492.2		1.57	(26%)
Ankara	Base Case	20249.8	4584.1	1.30	0.29
	Combined Strategy (WR+IIT)	15665.7		1.01	(23%)
Antalya	Base Case	8049.9	648.9	0.51	0.04
	Window Renovation	7401.0		0.47	(8%)
Diyarbakır	Base Case	19067.0	2220.3	1.22	0.14
	Window Renovation	16846.7		1.08	(11.5%)

Table 6.3: Energy demand and savings of school building in cooling season

Cities	Case Type	Energy Demand (kWh)	Energy Savings (kWh)	Cooling Load (kwh/m2)	Cooling Load Saving (kWh/m2)
İstanbul	Base Case	781.2		0.05	0.03
	Combined Strategy (WR+SD)	312.4	468.8	0.02	(60%)
Ankara	Base Case	1434.1		0.09	0.04
	Combined Strategy (WR+SD)	784.0	650.1	0.05	(45%)
Antalya	Base Case	1968.1		0.12	0.05
	Combined Strategy (WR+SD)	1088.4	879.7	0.07	(42%)
Diyarbakır	Base Case	4433.7		0.28	0.10
	Combined Strategy (WR+SD)	2907.0	1526.7	0.18	(36%)

Energy savings for winter period and summer period can be seen in Table 6.4 and total energy saving costs can be seen in Table 6.5. It is assumed that natural gas is used in this school building for heating energy demand and unit price is 0.07 TL per kWh [24]. It is assumed that electrical energy is used in this school building for cooling demand and unit price is 0.17 TL per kWh.

Table 6.4: Total energy saving potential of school building

Cities	Energy Savings (kWh)		
	January	15 May-15 June	Total
İstanbul	1604.0	468.8	2072.8
Erzurum	8298.0	-	8298.0
Ankara	4584.1	650.1	5234.2
Antalya	648.9	879.7	1528.6
Diyarbakır	2220.3	1526.7	3747.0

Table 6.5: Total energy saving costs of one school building

Cities	Energy Saving Costs (TL)		
	January	15 May-15 June	Total
İstanbul	112.00	79.00	191.00
Erzurum	580.00	-	580.00
Ankara	320.00	110.00	430.00
Antalya	45.00	149.00	194.00
Diyarbakır	155.00	259.00	414.00

6.2. Determining the Total Energy Saving Costs for all Schools in Cities

Total saving costs according to the number of schools in İstanbul, Erzurum, Ankara, Antalya and Diyarbakir are seen in Table 6.6.

It is assumed that natural gas is used in these school building. Unit price of natural gas for school buildings and is 0.07 TL per kWh[24]. Total cost gain for one school building is 191 TL in İstanbul, 580 TL in Erzurum 430 TL in Ankara, 194 TL in Antalya,and 414 TL in İstanbul. There are 1420 school buildings in İstanbul, 1180 school buildings in Erzurum, 1300 school buildings in Ankara, 1069 school buildings in Antalya, 1183 school buildings in Diyarbakır. If it assumed that all school buildings are same type total energy cost gain for all schools are 271,000.00 TL in İstanbul, 684,000.00 TL in Erzurum, 559,000.00 TL in Ankara, 207,000.00 TL in Antalya, 489,000.00 TL in Diyarbakır..

Table 6.6: Total savings costs of all schools in different climate zones

Cities	Total Saving Costs (for one school) (TL)	Number of Schools	Total Saving Costs (for all schools) (TL)
İstanbul	191.00	1420	271.000.00
Erzurum	580.00	1180	684,000.00
Ankara	430.00	1300	559,000.00
Antalya	194.00	1069	207,000.00
Diyarbakır	414.00	1183	489,000.00

Total saving cost for all characteristic cities is 2,210,000.00 TL. While calculating energy savings potential and saving costs, it is assumed that January is the coldest month, and 15 May- 15 June is the hottest period during the school days. All these calculations are made and got the results for January as heating period and 15 May- 15 June as cooling period.

6.3. Results

Energy savings of type primary school buildings in Turkey by making renovation strategies has been determined in Chapter 5. In this chapter firstly climate regions in Turkey and properties of selected primary school, boundary conditions of this building have been defined. After defining which renovation strategies can be used in this building defined, application of simulation has been conducted by using

Thermplan-TRANSIT simulation programme. For every climate region, energy demand for base case and for renovation strategies have been evaluated. Total energy demand for summer period, for winter period and for annually have been calculated, then energy demand for renovation strategies have been compared with base case, energy savings have been determined. Lastly according to number of schools for each region have been determined and total energy savings for whole characteristic city has been calculated. While determining the economical savings, for winter period, for heating energy demand it has been assumed that natural gas has been used. Unit cost of natural gas for 1kWh has been taken; for summer period, for cooling energy it has assumed that electrical energy has been used and unit costs of electrical energy for 1 kWh has been taken.

Window renovation has been used for both winter and summer period calculations. U-value of windows has been decreased from 2.84 W/m2K to 1.24 W/m2K. Window renovation strategy and increasing insulation thickness strategy has been also used for both winter and summer period calculations. On the other hand shading devices have been used only for summer period.

In İstanbul in mild-humid climate region calculation have been made for base case, window renovation, shading devices and combined strategy renovations. Combined strategy renovation calculations have been made only for summer period as in winter period shading devices have not been used. By using window renovation energy savings are %11 in winter period, %20 in summer period and %12 for annually results when the calculations compared with base case. According to the shading devices renovation strategy, energy saving for summer period is %60. If combined strategy (window renovation+shading devices) is used energy saving for summer period is %60.

In Erzurum in cold climate region calculation have been made for base case, window renovation, increasing insulation thickness renovation and combined strategy renovation. In Erzurum only heating energy demand has been calculated as even in summer period there has been an heating demand for building. By using window renovation energy saving is %19. When insulation thickness is increased, energy saving is % 8 and by using combined strategy energy saving is %26.

In Ankara, in mild-dry climate region calculations have been made for base case, window renovation, increasing insulation thickness, shading devices and combined strategy. By using window renovation energy savings are % 14 for winter period, %34 for summer period and % 15 for annually results when the calculations compared with base case. If insulation thickness is increased, energy savings are %10 for winter period and %9 for annually results. In summer period increasing insulation thickness has negative effect on cooling demand and cooling demand has increased 67.3 kWh when the calculations compared with base case.Because incerasing insulation thickness obstructs night cooling. Combined strategy for winter period means using window renovation and increasing insulation thickness together, for summer period combined strategy is using window renovation, increasing insulation thickness and shading devices. By using combined strategy energy savings are %23 for winter period, %45 for summer period and % 24 for annually results.

In Antalya, in hot-humid climate region calculations have been made for window renovation, shading devices renovation and combined strategy. Combined strategy calculations have been made only for summer period as in winter period they are not used. By using window renovation energy savings are %8 in winter period, %25 in summer period and %11 for annually results when the calculations compared with base case. By using shading devices, energy saving for summer period is %34. By using combined strategy (window renovation+shading devices) energy saving for summer period is %42.

In Diyarbakir, in hot-dry climate region, calculations have been made for window renovation, shading devices renovation and combined strategy. Combined strategy calculations have been made only for summer period as in winter period they are not used. By using window renovation energy savings are %11,5 in winter period, %22 in summer period and %14 for annually results when the calculations compared with base case. By using shading devices, energy saving for summer period is %22. By using combined strategy (window renovation+shading devices) energy saving for summer period is %36.

After evaluating the energy demand of school building, number of schools in characteristic cities for climate zones have been determined and total cost savings have been calculated. While evaluating the total cost savings it has been assumed that combined strategy has been used for both winter period and summer period.

Calculation have been made and total energy savings are 2072.8 kWh for İstanbul, 8298.0 kWh for Erzurum (only heating), 5234.2 kWh for Ankara, 1528.6 kWh for Antalya and 3747.0 kWh for Diyarbakır. Then costs have been calculated and total energy saving costs for all schools in one city have been determined. These saving costs are nearly 2.2 million TL. (for January and 15 May–15 June period)

7. CONCLUSION

In the present work energy savings of primary school buildings in Turkey by making renovation strategies are determined. Primary school education, energy consumption in Turkey, energy efficient design and parameters are mentioned, then energy consumption of primary school buildings in different climate zones are evaluated by making renovation strategies in building envelope.

After the petrol crisis in 1970's, energy sources are investigated instead of fossil fuels. For reducing the energy demand of buildings, passive systems for building design became popular. By taking into consideration of climatic conditions, site, form, orientation and building envelope it can be possible to reduce the energy demand of building.

The prior aim of designing building is to provide convenient spaces according to the biological, psychological and sociological requirements. Climate comfort conditions have an important effect on people's health and motivation on their work. Using passive systems in buildings, supplies, healthy buildings which have ideal comfort conditions. Only integrating active systems to the buildings and ignoring passive sytems can not supply ideal comfort for occupants, furthermore it increases the energy demand.

As it is seen in part 3, buildings' consumption part is %36 according to the total energy comsumption. %79.5 part of energy source is fossil fuels. Whereas, Turkey has great amount of sustainable energy sources like solar energy and wind energy. Especially the solar energy is important because nearly every part of Turkey has great potential of solar energy.

In Turkey ratio of education building over all buildings is great because in Turkey young people has a great ratio in population . Renovations that are made in education buildings, especially in primary schools have positive economical effects, by reducing energy demand.

The primary school project that is used in this study is called “type” primary school design and planned in five different climate zones. In this study calculation have been made for five climate regions which are mild-humid climate (İstanbul), cold climate (Erzurum), mild-dry climate (Ankara), hot-humid climate (Antalya) and hot-dry climate (Diyarbakır) in Turkey. Energy demand of this building has been calculated by the Thermplan- TRANSIT simulation program. January which is the coldest month has been assumed as the heating period and 15 May-15 June has been assumed as the cooling period. While calculating the energy demand, firstly base case has been calculated, and then the results which are attained by renovation strategies have been compared with the base case. These renovation strategies are window renovation (for winter and summer period), increasing insulation thickness (for winter and summer period) and adjustable shading devices (for summer period). Adjustable shading devices are not used in winter period because of increasing the heating demand of building. These shading devices do not transfer the sun light that is why they are used for to shade only the %20 of window area. Thus, it is aimed not to have negative effect on lighting of classrooms.

According to the results, energy savings are changing between %11 -%60 when renovation strategies compared with the base case.

Window renovation as reducing the U- value from 2.83 to 1.24 W/m2K is an effective way for saving energy. With window renovation, energy savings percentage change between the ratio %8 to %19 in heating period and between the ratio %20 to %34 in summer period. With increasing insulation thickness in Erzurum energy saving is %8 while in Ankara it is %10 in heating period. In Ankara increasing insulation thickness has an negative effect in cooling period which increased the cooling energy , but annually results energy saving is % 9. Because increasing insulation thickness obstructs night cooling. Shading devices are used only in cooling period; it has an energy saving percentage between the ratio %22 to %60. Combined strategy is so effective especially in summer period which has a saving percentage %60 in İstanbul for cooling energy demand. All these calculations have been made in January as heating period and 15 May- 15 June as cooling period. Total energy saving cost is nearly 2.2 million TL, if the whole cooling and heating periods are calculated these saving costs will be more. Especially heating season energy savings will be more if the calculations are made in whole heating period. Because in Turkey schools are in holiday, between 15 June-15 September which is the cooling period.

It is obvious that energy demand of building is reduced by using renovation strategies. These savings will be better if all the passive design parameters are applied to the building by taking into consideration climatic conditions. This primary school building design can be different for all climatic zones, because when the energy efficient design parameters are thought this design is not suitable for some climatic zones. For example in Erzurum for cold climate it have to be compact form and have less glazing area, or building envelope design have to be different for Antalya and Diyarbakır. These renovations are in building envelope and with this renovations energy can be saved. In addition active systems also have importance on energy consumption for instance reducing electrical energy consumption. As it is seen in the case study in Stuttgart that, electrical equipment usage time also has an important effect on electrical energy consumption. Non-occupation hours when the equipments are stand-by mode are more than the occupation hours when the equipments are on. Making very simple application, as switching of computers at weekends and non-occupied times instead of leaving them stand-by, electrical energy demand is reduced.

In Turkey to get more energy savings there can be different type primary school building designs applied in different climate zones. In this study renovation strategies in building envelope both in transparent and opaque components have been recommended and energy savings have been calculated for heating and cooling energy. In addition, lighting consumption and electrical energy consumption must be calculated. Furthermore other renovation strategies like trombe wall, thermal mass can also be used to reduce the energy demand for the further studies. Last decisions about renovation strategies must be taken after cost analyses.

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