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BAHÇEŞEHİR ÜNİVERSİTESİ

PERFORMANCE ANALYSIS OF PASSIVE SOLAR BUILDINGS

Master Thesis

MAHMUD SAMİ ARPACI

İSTANBUL, 2014

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Istanbul, 2014 Mahmud Sami Arpacı

ABSTRACT

PERFORMANCE ANALYSIS OF PASSIVE SOLAR BUILDINGS

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Energy needs in our rapidly developing world constantly escalate. Especially after the industrial revolution these needs have been satisfied of fossil fuels. However, energy generation by fossil fuels bears byproducts causing serious environmental damage. Inattentively excessive usage of these sources specifically brings about great danger to nature and our future. Currently the effects of the damage are observed explicitly and have been disturbing our daily lives; ergo, immediate measures ought to be taken and regulations of energy generation and consumption to be made. Executing these regulations is relatively easier for developing and evolving countries such as Turkey with respect to developed countries.

Environment friendly energy generation techniques need to be sought and examined. Existing energy needs should be covered with sources which do not harm nature and their utilization should be improved. Meanwhile in order to achieve proliferation and adoption of alternative sources by the society certain practices need to be introduced.

The sun is the biggest and cleanest renewable energy source we have. Usage of sun energy instead of fuel for heating of the buildings is investigated primarily in this study. Taking advantage of the fact that solar radiation exposure period is long in Turkey due to geographical properties, passive use of the sun is investigated thoroughly.

Examinations have been done to lay out the results of passive use of the sun in conditions of Turkey. Buildings from places with similar weather conditions to Turkey and buildings constructed in Turkey were analyzed with different methods by computer software. As the output report of the analyses were compared and evaluated, the studies were concluded.

Keywords: Passive Solar Energy, Passive Architecture, Energy Performance Analysis, Energy Production in buildings

ÖZET

PASİF SOLAR YAPILARIN PERFORMANS ANALİZİ

Mahmud Sami Arpacı

Mimarlık

Tez Danışmanı: Prof.Dr., Sema Soygeniş

Nisan 2014, 56 Sayfa

Sürekli hızlanarak gelişen dünyada, enerji ihtiyacı tırmanmaktadır. Ortaya çıkan bu ihtiyaç özellikle sanayi devriminden sonra fosil yakıtlar üzerinden karşılanmaktadır. Oysa ki fosil yakıtlardan enerji üretimi beraberinde doğaya zararlı maddeler ortaya çıkarmaktadır. Özellikle bu kaynağın bilinçsizce aşırı kullanımı doğal çevre ve gelecek için ciddi bir tehlike oluşturmaktadır. Günümüzde doğaya verilen zararların etkileri net olarak gözükmekte ve yaşamı etkilemektedir. Dolayısıyla yakın gelecekte enerji üretim ve tüketim kültüründe düzenlemeler yapılmalıdır. Özellikle Türkiye gibi gelişmekte ve büyümekte olan ülkelerin, bu düzenlemeleri hayata geçirmesi, gelişmiş ülkelere nazaran daha kolaydır.

Enerji üretiminde, çevreci yöntemlerin araştırılıp kullanılabilirliğinin tecrübe edilmesi gerekir. Var olan enerji ihtiyacının karşılanmasında doğaya zarar vermeyecek kaynaklara yönelip, bu kaynakların kullanımının geliştirilmesi gerekmektedir. Aynı zamanda bu alternatif kaynakların kullanımının toplum tarafından benimsemesi ve yaygınlaşması içinde çalışmalar yapılmalıdır.

Güneş sahip olduğumuz en temiz, büyük ve tükenmeyen enerji kaynağıdır. Yapılan çalışma öncelikle güneş enerjisinin yapılarda ısıtma için harcanan yakıtların yerine kullanımını incelenmiştir. Türkiye coğrafyasında güneşlenme sürelerinin bolluğuna odaklanılarak, güneşin pasif olarak değerledirilebilirliği araştırılmıştır.

Güneş enerjisinin pasif olarak kullanımının Türkiye şartlarındaki sonuçlarını ortaya koymak için incelemeler yapılmıştır. Türkiye’ye benzer iklimsel fiziksel çevre şartlarında ve Türkiye’de inşa edilmiş yapılar farklı yöntemlerle bilgisayar yazılımı kullanılarak analiz edilmiştir. Çıkan analiz raporları karşılaştırılıp, değerlendirilerek çalışma neticelendirilmiş ve sonuca ulaşılmıştır.

Anahtar Kelimeler: Pasif Solar Enerji, Pasif Mimarlık, Enerji Performans Analizi, Enerji Üretimi

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FIGURES

SYMBOLS

Celsius, centigrade	:	°C
Kilojoule	:	kj
Kilowatt-hours	:	kWh
Kilowatt-hours to square meter	:	kWh/m^2
Kilogram	:	kg
Cubic meter	:	m^3
Kelvin	:	K
Meter	:	m
Watt	:	W
Nevşehir building original version	:	nV°
Nevşehir building case 1	:	nV^{1}
Nevşehir building case 2	:	nV^{2}
Nevşehir building case 3	:	nV^{3}
Nevşehir building passive version	:	nV^{P}
Nevşehir passively designed building	:	nP
Reinforced Concrete	:	RC
Turkey	:	TR
United States	:	U.S.
Van building original version	:	vV°
Van building case 1	:	vV^{1}
Van building case 2	:	vV^{2}
Van building passive version	:	vV^{P}
Van passively designed building	:	vP

1. INTRODUCTION

The Sun is an approximately 4.6 billion-year-old massive source of energy and life (Meadows, 2007, p. 17). Every day the sun, with its mass and radiation in the form of heat and light enables the earth to be a habitable planet. The sun, having energy with the lifespan of billions of years, is a renewable source. The energy sources which restore themselves and do not deplete with time, with respect to the lifespan of human beings, are called renewable energy sources. Despite possessing immense energy potential, the sun is not used as the primary energy source by humans.

Instead, the fossil fuels are used in industry, transportation, electricity generation and heating. Sources such as oil, natural gas, coal are fossil fuels and are called non-renewable energy sources. These sources are non- recyclable after use, but there is sufficient amount of them that allows to constitute a sustainable economy on the human timescale. As a consequence of being the primary preference as energy source, there is extensive consumption of fossil fuels. Contrary to the sun energy, fossil fuels emit waste which is lethal to human body, and excessive usage of these sources harms the environment and nature. Fossil fuels, being non-renewable sources indicate that their supplies in nature has been declining constantly and that someday they will be completely exhausted.

These problems which arise from the use of fossil fuels led people to pursue an environment-friendly and sustainable alternative source. Geothermal, hydraulic, wind and the sun energy are the renewable energy sources. Among these sources, the sun has the easiest accessibility and the biggest capacity on the earth. Due to these properties, it should be used more efficiently and frequently.

1.1 DEFINITION OF THE PROBLEM

Humans need sources, like oxygen, water and food that are found in nature, for survival. From the primitive societies to contemporary civilizations raw materials used for production of textile, transportation, agriculture and construction have been provided by nature. Research that focused in all historical and contemporary eras reveal that the energy and sources, for all kind of continuity in human life and social sustainability, are always provided by nature. This fact affirms the absolute bound between nature and human beings.

Nature is known to be the origin of unlimited sources for all materials it has. By building cities and mega structures with these sources, humans have formed and developed natural environment. Development in agriculture and industry strengthens the transformation of natural environment. From primitive ages to contemporary eras human beings have spent colossal amounts of labor for transforming close natural habitat to generate a convenient and favorable social life style (Spirkin, 2014). Before the industrial society, the effect of human labor (work force) on natural habitat was relatively insignificant. After industrial revolution, construction of modern life has developed wastes like carbon monoxide, sulfur oxide, heavy metals, radioactive contaminants and others. The culture of high consumption, such as automobile usage, technologic tools, cosmetics, cleaning supplies, plastic and paper industry, etc. in modern society has caused increase of those wastes. Global warming, acid rains, air pollution, contamination of soil and fresh underground water are some of the side effects that have been created by the wastes of industrial era. Nature assimilated the wastes of human labor until the intense rise of industrialization in the eighteenth century (Spirkin, 2014). As a result of rapid development, amount of waste has increased, also advancements in technology led to more harmful wastes which have started to disturb the natural balance.

The dynamic balance between nature and society has started to show signs of disturbance. The contamination that was produced by people not only threatens contemporary age but also has serious effects on future generations. Generally the study focuses on means of protecting and strengthening the dynamic bound between nature and human for continuation of livable environment on the earth.

1.2 HYPOTHESIS AND AIM

The understanding and awareness of environmental consciousness are needed to protect the dynamic bound between human and nature. To protect the dynamic bound, people who are inside the production and consumption chain need to have environmental consciousness. Also architects need to practice with similar awareness as a part of the society. Presently there are many concepts regarding the awareness of environment in architecture. The utilization of passive solar energy is one of the concepts. Passive solar systems use the energy of solar radiation, via architectural components of a building, for the heating and cooling needs of a building. The aim of this study;

- **a.** The main aim: This study focuses on finding the differences between types of contemporary buildings concerning the solar energy gain, the ones constructed with the approach of passive solar energy in architecture and the ones without a passive solar approach.
- **b.** Secondary aim: Argues the importance of use of passive solar energy via calculation and comparison of the energy gains of a buildings and with the use of passive solar concept. At the same time indirectly, enables the researcher who makes use of this study to;
  - **i.** Become familiar with the concepts of environmental awareness.
  - **ii.** Understand the benefits of using the sun and the geographical circumstances during the design process.

Hence, it aspires to the advancement and the dissemination of passive solar energy awareness.

1.3 IMPORTANCE

Renewable energy sources are powerful enough to affect both the environment and global energy economy (Foster, 2010, p. 1). Using solar power and having conscious society about renewable energy sources have vital importance on habitat and economy. Renewable energy sources are non-polluting and carbon free, so they do not have negative impact on nature (Foster, 2010, p. 4). Renewable energy sources could be found on biosphere with vast amounts and they are sustainable, consequently tendency for renewable energy sources will reduce the expenses in production of energy. In this context, studies that focus on environmental balance and usage of renewable energy sources have vital importance for environmental consciousness.

Environmental awareness also involves the concept of urban identity. Over time, the concept of “identity” in cities of Turkey suffered from economic and social developments (Kiper, 2013, p. 73). At the present time urban renewal projects have an identity loss (Gür, 2012, p. 2). To create an identity in the future, which has concerns about environment and renewable energy, is essential. This new identity will ensure formation of cities that have environmental awareness.

This study focuses on solar passive systems and questions efficiency of the application of this system, in detail. Additionally this study reveals the difference in energy consumption between passive and non-passive buildings.

1.4 LIMITATION

The energy performance evaluation between passive solar systems and non-passive ones is made via residential samples. The energy gains using architectural components are examined. Solar energy gains and energy loses caused by design approach are in boundaries of this study. The fact that 70 percent of the overall constructions are residential, is the reason in selecting residential building type (TUIK, 2014). Buildings are selected from similar climatic conditions with geographically close parallel zones as case studies. Analyzed buildings are located especially in areas with severe winter conditions to see the energy expenditure and test solar passive energy approach if it effectively could gain energy between (in -5 °C to 5 °C). Two different methods are used. At first, passive principles are applied to non-passive building to find out the energy performance difference from original design. Available principles such as direct gain windows, clerestories, interior thermall mass are applied one at a time to calculate the effect of the passive principles. Secondly a passive building design with similar physical specialties was evaluated to find out the differences. This study is focused on basic passive design decisions and basic physical rules on heat transfer. Chemical and physical characteristics of the building materials are kept out of boundaries of the research.

Energy performance analysis was made by Ecotect computer software with 3d models of selected buildings. The selected computer software is capable of measuring solar gains and analyzing physical features of the structure with respect to environmental conditions.

Ecotect is preferred for analysis, because of its wide range of usage capabilities and accuracy (EERE, 2011). To focus on evaluation of analysis only results of the digital simulation were taken into consideration. Thus manual of computer software, algorithms of digital calculations are not included.

The results of analysis are evaluated by the means of design approaches and decisions. Hence, the subjects such as the budgets of projects, properties of the chosen construction materials were excluded. Furthermore, these excluded subjects were considered ineffective to this study and were not included to the concentrated research field.

1.5 METHODOLOGY

In this study, primarily energy and solar passive energy concepts are researched. Later surveys are run on digital simulations to calculate effects of studied fields. The subjects that do not directly belong to, yet indirectly related to the focused field, are studied and presented as needed to support perception. To support the research topics, basic graphics and sketches are used in this study.

In the second chapter solar and fossil-derived energy are researched. To concentrate on the case studies, the sun as a renewable energy sources is researched. The energy flowing from the sun to the earth is examined from outer space to geographic environments in biosphere (Pittock, 2009) (Phillips, 1992) (Stix, 2002) (Lydolph, 1985). Moreover, fossil fuels are introduced. The importance and potential of solar energy use for Turkey are reviewed, also comparisons with world’s leading countries on usage of solar energy are made through this review.

In third chapter, passive solar energy concept is researched (Chiras, 2002) (DeKay & Brown, 2014) (Levy, Evans, & Gardstein, 1979) (Mazria, 1979). The differences in architectural components that consist of the solar passive energy concept are introduced. Passive solar energy is researched in three principles. Those are layout, structural and efficiency principles. Layout principles contain design decisions that are used in the preliminary stages of the design. Selection of the site, orientation and form, floor layout, space and wall openings are discussed in layout principles. Windows, walls, skylights, sunspaces are modified architectural components in order to gain solar energy and they are analyzed in structural principles. Finally efficiency principles focus on matters during construction and building use.

In the fourth chapter, climatic characteristics of Turkey are reviewed. Cities in Turkey are grouped according to the average climatic and temperature statistics. Two regions are selected from the group according to their climate data in relation to the average temperatures of Turkey. Two residential building projects (one non passive building and one passive building) are selected from each region for case studies. Different cases are created for non-passive example by incorporating the passive design principles to the projects. Then energy performance of the projects were surveyed by the Ecotect computer software. The results are evaluated for each case.

2. ENERGY

To move, to do work one needs a specific quantity of power. The consumed quantity of power for every form of action that takes place is called energy. Since there is no knowledge on what energy really is, the definition becomes extremely primitive, however there are formulas to calculate the numerical quantity of energy (Gotolieb & Pfeiffer, 2010, p. 4.2). In the universe, this quantity of power flows in different forms like; thermal energy, chemical energy, electric energy, radiant energy, magnetic energy and more.

Energy is needed for every form of life and movement to exist. Energy also generates habitable environments for life to exist. For instance, the sun heats the earth with its radiant energy. Since life and movement need energy, all the industries on the earth are dependent on energy as well. The necessary energy for industries to operate is achieved with many different ways. Nuclear power plants, solar collectors, dams, wind mills are some of the approaches to gain energy, as seen in the figure 2.1. The most contemporary common method to get energy is with the consumption of fossil fuels.

Figure 2.1: Energy production approaches

Source: 1 Arturo Ramo, (February 2007) http://en.wikipedia.org/wiki/file:limerickpowerplant.jpg, 15.january.2014

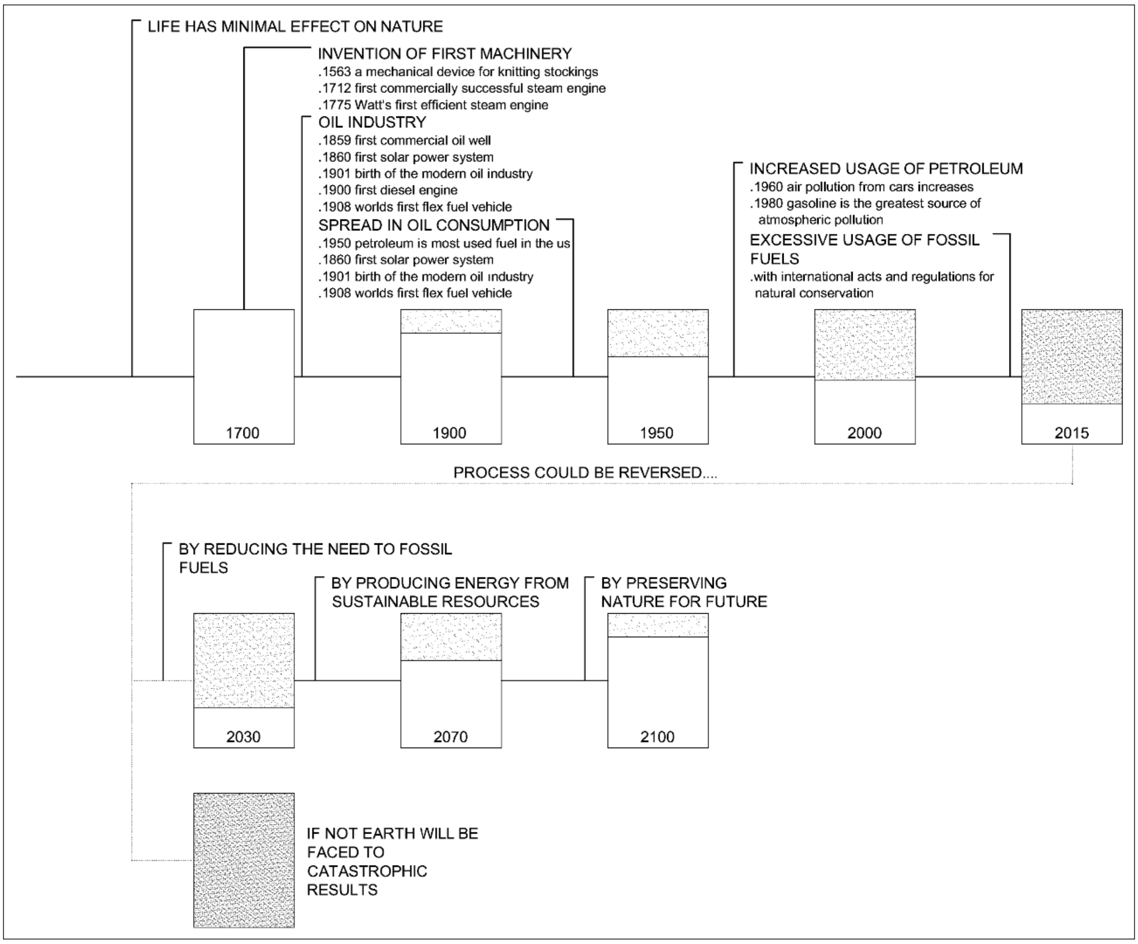
2 Hans Hillewaert, (September 2008) http://en.wikipedia.org/wiki/File:Windmills_D1 -D4_(Thornton_Bank).jpg, 15.january.2014
3 U.S. department of the interior bureau of land management, (December 2013) http://www.blm.gov/ca/st/en/prog/energy/solar.html, 15.january.2014
4 JJ Harrison, (September 2008) http://en.wikipedia.org/wiki/File:Gordon_Dam.jpg, 15.january.2014

Today, fossil fuels are also used in buildings as the main heating fuel. As a secondary source of heating and cooling, electric is used with air conditioning units. Before industrial revolution and vast consumption of un-renewable energy sources, environmental conditions were considered to get benefit of them. Buildings' heating requirement was solved by using principles generated by combination of basic laws of physics and environmental components like the sun and geographical orientation. This method of capturing energy while it flows in nature is called passive energy usage. Passive energy systems shares more common principles with vernacular architecture. Similarities between vernacular architecture and passive solar systems constitute from their approach to physics and environment. The knowledge that has been gathered from trial and error, natural habitat conditions such as climate and topography, relationships between humans, basic science awareness, native building materials, even religions, playes a huge role in formation of vernacular architecture. Even in ancient eras, in the times of Socrates, there was the knowledge of how to use the sun in housing to receive heat in winter and cool down in summer (Xenophon, 531-431 B.C., p. III.vii).

Excesive usage of fossil fuels as a main resource of energy has created many problems in time. Nature itself and living organisms on the earth have been suffering from those results. Using fossil fuels generates emissions of carbon dioxide that causes greenhouse effects on the earth (Pittock, 2009, pp. 11,157). Also burning fossil fuels generates sulfuric, carbonic and nitric acids which cause acid rains. The consequences of using fossil fuels have triggered development environmental awareness. Dependence on fossil fuels for energy, has increased the importance of fossil fuels. Controlling fossil fuel reserves helps countries to gain global power over other countries because of its value and capacity. Countries shape their politics on controlling fossil fuels, since usage and extraction of fossil fuels define political relationships between nations all around the world.

Inconsistency of fuel prices, impacts of vast usage of fossil fuels, lack of confidence in energy politics have raised the demand on alternative energy resources. Usage and developments on geothermal energy, wind power, hydropower, solar energy, biomass, biofuel, geothermal energy and ocean genic power, have been increased to cover energy produced by fossil fuels. Furthermore alternative energy resources are less harmful to environment. By the usage of renewable energy resources, remediation of environment is also aimed as seen in the figure 2.2. Industries have started to give priorities to environmentally responsible concepts and products. Buildings consume approximately 25 percent to 40 percent of the energy produced for heating and cooling (Çetiner & Metin, 2011, p. 866). In Turkey consumed energy for heating and cooling by residential buildings is 31 percent (Koçak, Şaşmaz, & Atmaca, 2012, p. 2).

Figure 2.2: Remediation of environment



In the last couple of decades, building industry has gained different terminologies for alternative energy concepts. Some of those terms are known as; ecological building, low energy or zero energy building, zero impact design, sustainable design, eco design, green building, passive solar energy. Generally those terminologies are about; Energy saving, low energy usage, zero emitting building material usage, production of energy and less fossil fuel dependent production of energy. Most of them are successful approaches for energy efficientcy and they are available for applications with low budgets, while some of those concepts are experimental and under development.

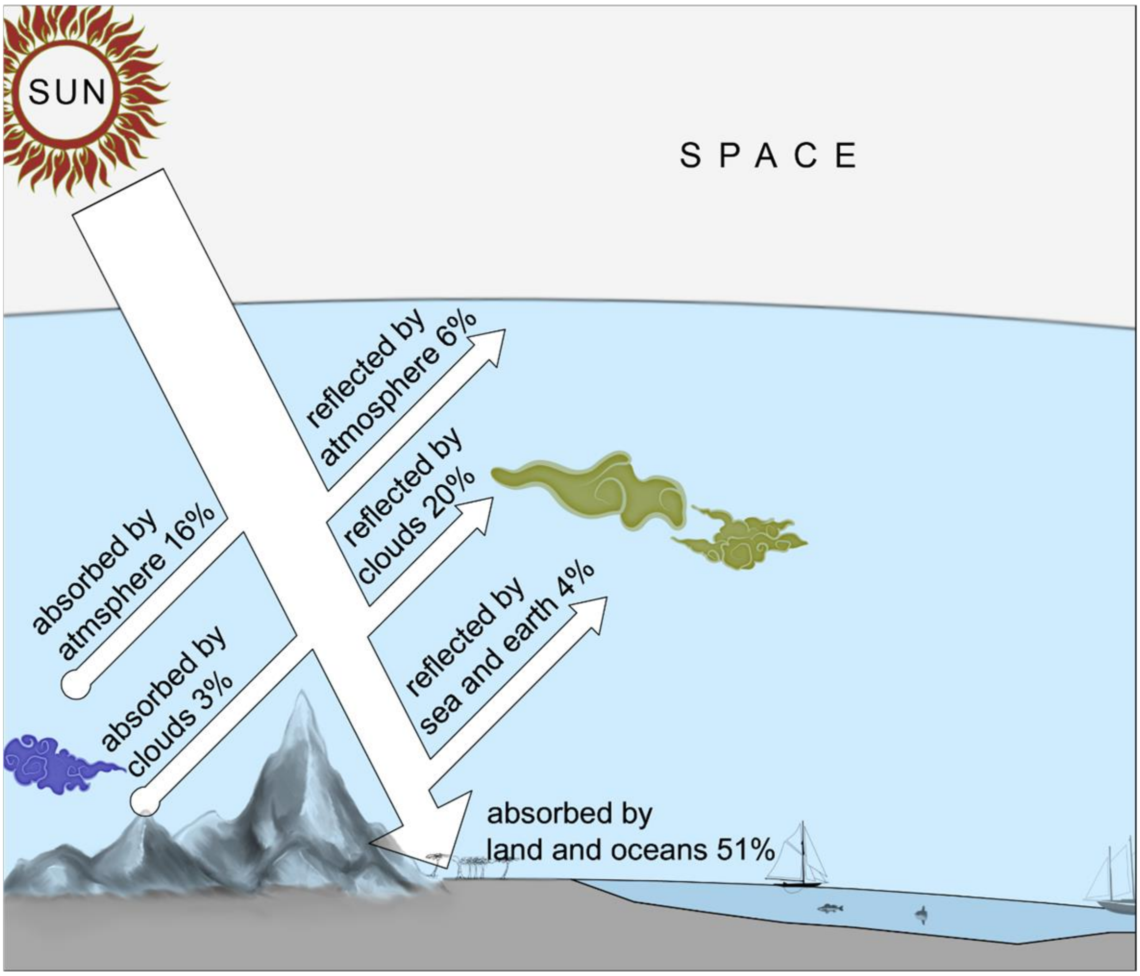
2.1 SUN ENERGY

The sun is the source of life and energy in our solar system. It is 4.6 billion years old and it still has an enormous energy for billions years more (Meadows, 2007, p. 17). The sun converts 4.2 million tons of mass into energy every second in its core at approximately 15 million Celsius (Phillips, 1992, p. 51). Even though that amount of mass is enormous, it is tiny when considering the total mass of the sun. While the total amount of mass of the sun is 2×10^{27} tons, it consumes only 2×10^{-20} percent of mass from itself each second (Stix, 2002, p. 2). The energy produced in the Sun travels in to space in the form of electric and magnetic waves or energy particles called photons. Radiation is emitted in all wavelengths in the sun.

Classifications for electromagnetic waves are made via wavelengths. When the radiations' energy load gets higher, its wavelength gets shorter (Seeds & Backman, 2011, p. 76). From the distance of 150 million kilometers, the earth receives approximately 1,368 W/m², which is called "Total Solar Irradiance" or TSI (Weier & Cahalan, 2003). This energy obtained by the sun every hour is equivalent to total energy used in one year on the earth (Morton , 2006, p. 19).

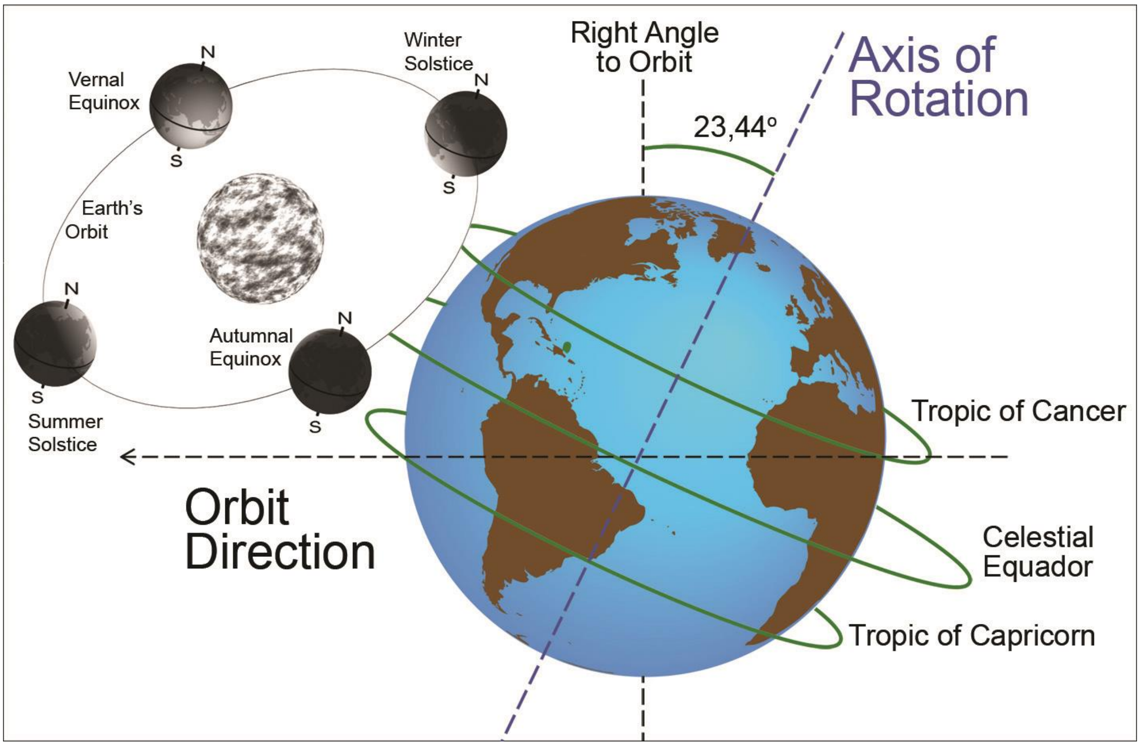
The energy received in the form of radiation from the sun is scattered in atmosphere. From 35 to 40 percent of this radiation is reflected back to space by clouds, sea and dust in the atmosphere. By reflecting this portion, the earth's temperature is prevented to be hotter (Lydolph, 1985, pp. 18-20). 20 percent of this radiation is absorbed by water vapor, dust and molecules in the air as seen in the figure 2.3. The absorbed portion illuminates the sky dome on the earth and becomes daylight. Generally the percentage received by the surface of the earth is relevant with the length of the atmosphere that radiation of the sun pass through from outer space until reaches the earth. The remaining portion of the radiation is absorbed by the earth's ground. After passing all the obstacles, the sun rays cannot be received evenly all around the globe.

Figure 2.3: Scattering of solar radiation



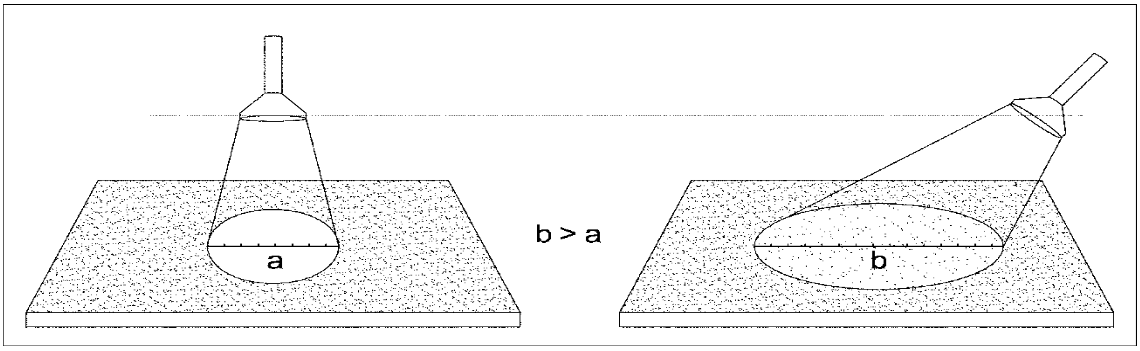
The earth has a tilted angle with respect to its orbit around the sun, as seen in the figure 2.4. The energy received from the sun shifts because of this position, and it has many effects on the earth. One of the reasons behind experiencing different climatic seasons with different temperatures on the earth during one year, is due to that tilted position. The three major reasons of summer being hotter and winter being colder are; the direct sunlight, the length of the way that the sun rays pass through the atmosphere and the course that the sun follows during the day in the sky dome.

Figure 2.4: Angle of Earth



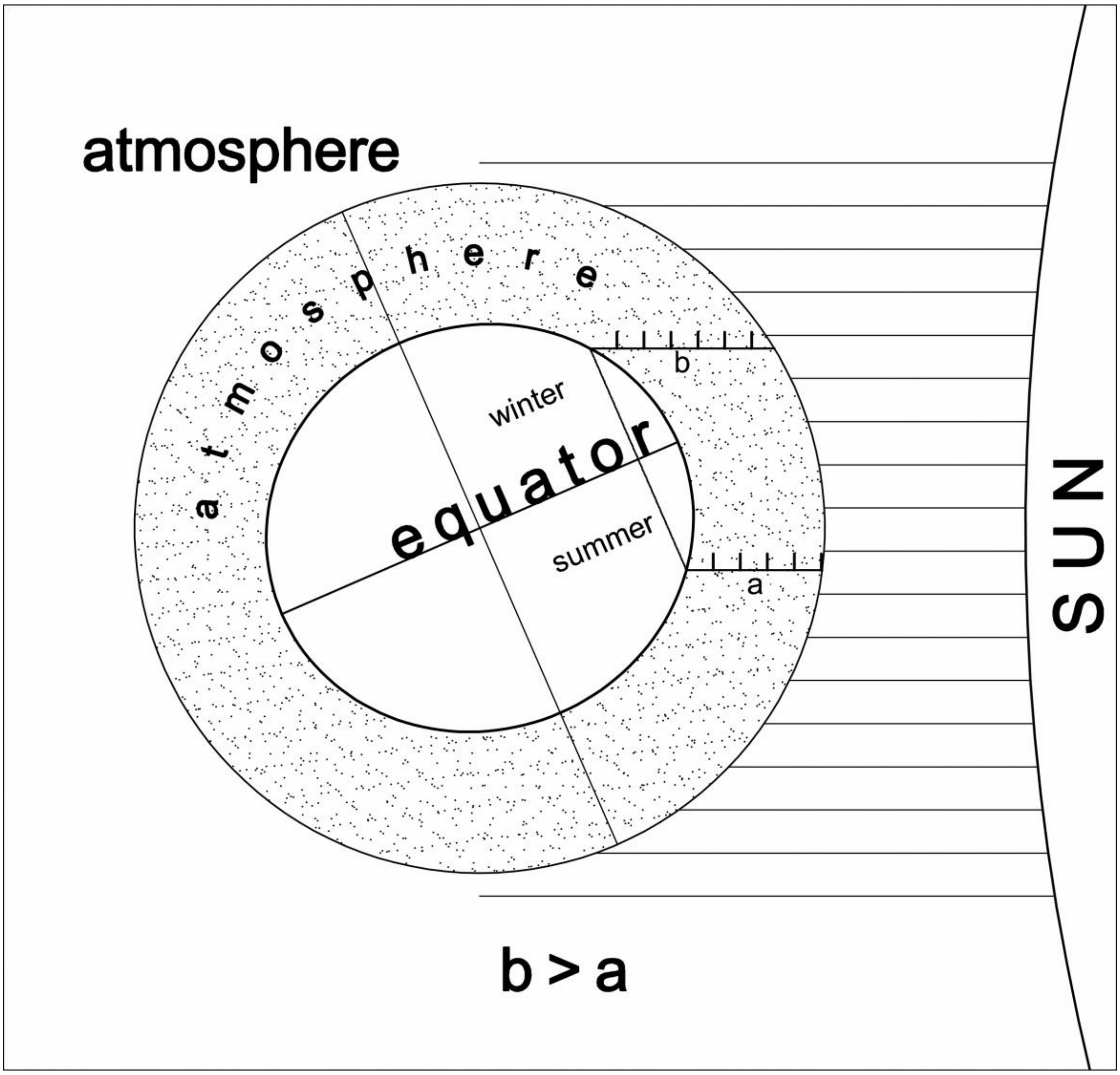
This tilted 23.5˚ angle, causes the sun rays to reach the earth more intense or sparser as seen in the figure 2.5, similar to area lit by a flash light with 90˚ angle to the table will be brighter than an angled position of the flash light. This angle causes the earth to receive more direct light at one hemisphere than another. Since direct sunlight is much warmer than an angled one, while north hemisphere experiences summer, south hemisphere experiences winter.

Figure 2.5: Flash light experiment



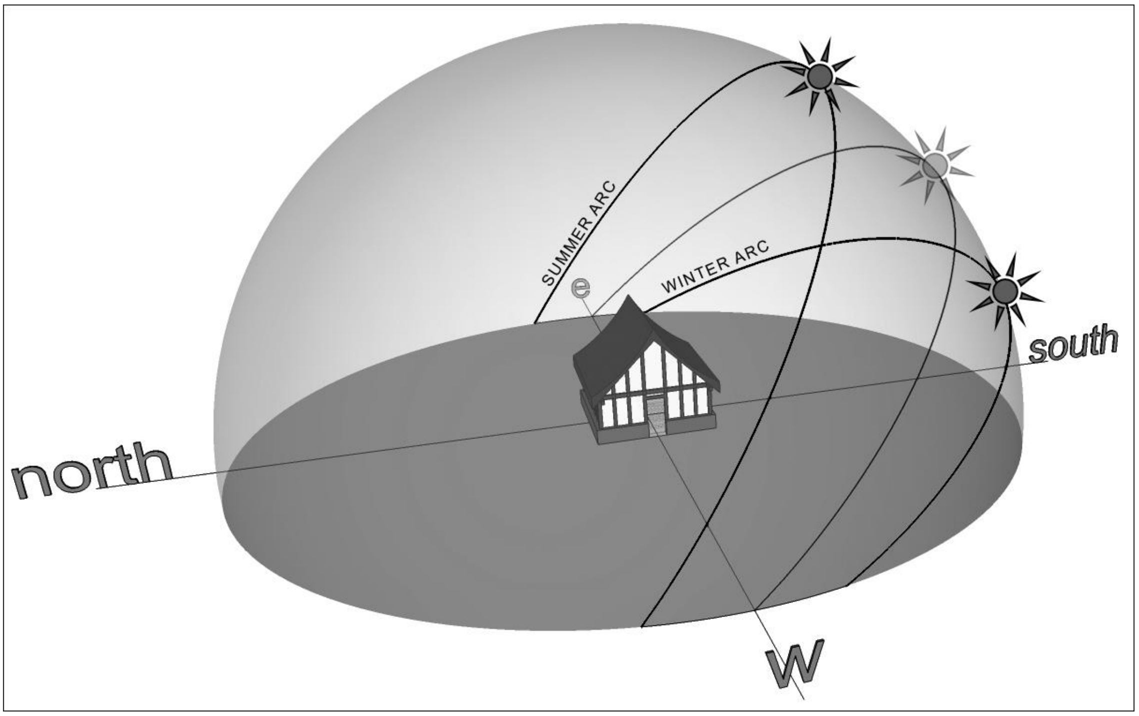
One of the reasons of low temperatures in winter is an increase in reflected sunrays back to space in atmosphere, as seen in the figure 2.6. If the length of path in atmosphere between outer space and surface of the earth increses, the reflected ratio rises. Likewise a shorter length increases the absorbed ratio and hereby the temperature.

Figure 2.6: The path in atmosphere



The Sun travels on a path in sky dome during day. It rises from east and sets from west. Between the rise and the set, the sun follows an arch in sky dome. This arch changes during seasons, as seen in the figure 2.7. In winter that course is lower and shorter. The lowest and shortest arch occurs on December 21. This effect causes colder winter days and short day times. Since the sun’s exposure is at minimum with respect to all year, temperature drops to its lowest levels. In summer, course of the sun is higher and longer. The longest and highest path occurs on June 21. This effect causes warmer summer days and longer day times. Since the sun exposure is at maximum with respect to all year, temperatures rises to its maximum levels. The sun path travels between two peak arches during a year.

Figure 2.7: Sun arches



2.2 ENERGY DERIVED FROM FOSSIL FUELS

Fossil fuels are generally used for generating energy. Fifty percent of the energy used on the earth is produced by fossil fuels. Additionally, products of fossil fuels are widely used in life.

Fossil fuels are formed by decomposition of buried dead organisms like plants and animals. Process for the formation of fossil fuels takes millions of years. While buried deep in the soil, with pressure and heat of the earth, coal, petroleum and natural gas are formed by chemical reactions.

Many different kinds of fuels are generated from petroleum such as; diesel, gasoline, jet fuel, fuel oil, liquefied petroleum gas (LPG), kerosene and others. They are called energy carriers. Beside, many other products are also generated from petroleum. Only approximately 45 percent of the petroleum is converted to gasoline, the rest is used as products such as; tar, waxes, petrochemicals, lubricants, asphalt and road oil (EIA, 2013). All of the petroleum products are very much integrated in life.

Today petroleum based on fossil fuels are used in many different areas of life. Numerous materials are produced from raw materials. Plastic, gasoline, many building materials, ink, tar are to name a few.

For centuries, all automotive industry has been simply based on consumption of benzene generated from fossil fuels, as seen in the figure 2.8. Also plastics are excessively used for; bottles, supermarket bags, pipes, car bumpers, electronic equipment cases and more.

Figure 2.8: High consumption of gas and traffic pollution

Source: 1 http://anemicroyalty.files.wordpress.com/2008/04/gasline1979_anemi.jpg?w=450, 16.january.2014
2 https://s-media-cache-ec0.pinimg.com/736x/fd/bd/39/fdbd3920fa065b83a10ea4fc9ca14cf7.jpg, 16.january.2014
3 http://img3.cache.netease.com/photo/0001/2013-05-22/8VFK0RKK00AN0001.jpg, 16.january.2014

Coal was the first fossil fuel adapted for human usage. For many centuries coal has been used as a source for heating. Coal played a massive role in the beginning of the industrial age. Today coal is still being used for many purposes. Today it is widely used for generating electricity by thermal power plants and generating heat. Separated ingredients of coal are used to make plastics, tar, synthetic fibers, fertilizers, and medicines (EIA, 2013). Coal is also used in steel, concrete and paper industries.

Natural gas is known as the most environmentally safe fossil fuel. Generally it is used to generate electricity in power plants. Many industries also run with natural gas. It is used to produce steel, glass, paper, clothing, brick, and electricity. Even natural gas is used as a raw material in some products like; paints, fertilizer, plastics, antifreeze, dyes, photographic film, medicines, and explosives (EIA, 2013). The other use of natural gas is in residential sector. In many cities it has been used as main heating fuel.

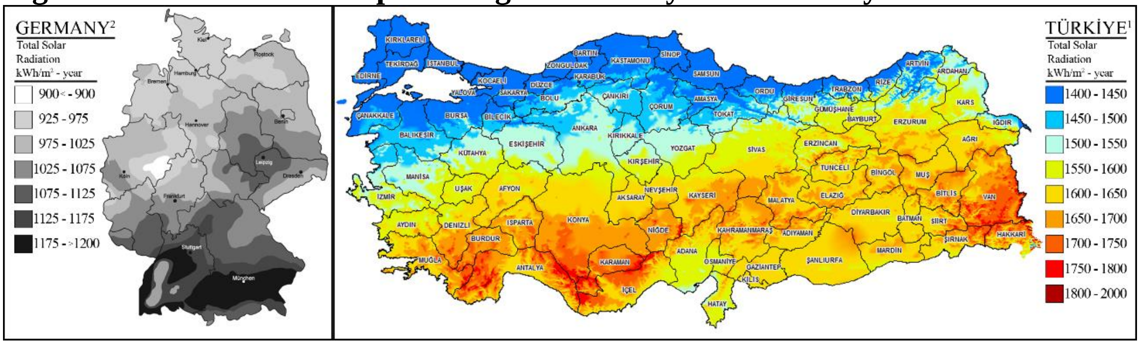
2.3 SOLAR RADIATION IN TURKEY

Solar energy is not received equally by every geographical point on the earth. Generally the received amount of energy increases when getting closer to equator and decreases when getting closer to poles. However the number of countries utilizing solar radiation for energy is very few. This situation is revealed from the annual amount of energy that has been produced from solar radiation by the countries (EIA, 2014).

Germany is the world leader country in utilizing solar radiation, because in 2011, Germany produced 19 billion kWh from the sun and increased this production to 28 billion in 2013 (EIA, 2014). Germany is followed by Italy with 18.8 billion kWh in 2013 (EIA, 2014). For today, Turkey, recently started to change in energy politics on utilizing solar radiation.

Annual solar radiation in Turkey is 1400k Wh/m^2 as seen in the figure 2.9. This ratio is increased to 2000 Wh/m^2 in southern areas of Turkey (Yenilenebilir enerji genel müdürlüğü, 2012). In contrast to Turkey, Germany has 1100 Wh/m^2 average and solar radiation which only increases to 1200 Wh/m^2 annually as seen in the figure 2.9 (Kaltschmitt, Streicher, & Wiese, 2007, p. 41). Even Germany has less solar radiation exposure than Turkey, Germany utilizes the sun most in the world.

Figure 2.9: Solar radiation percentages in Turkey and Germany



Source: 1 YEGM, http://www.eie.gov.tr/MyCalculator/Default.aspx, 21.may.2013
2 Martin Kaltschmitt, (2007) Renewable Energy: Technology, Economics and Environment, Springer, p.41

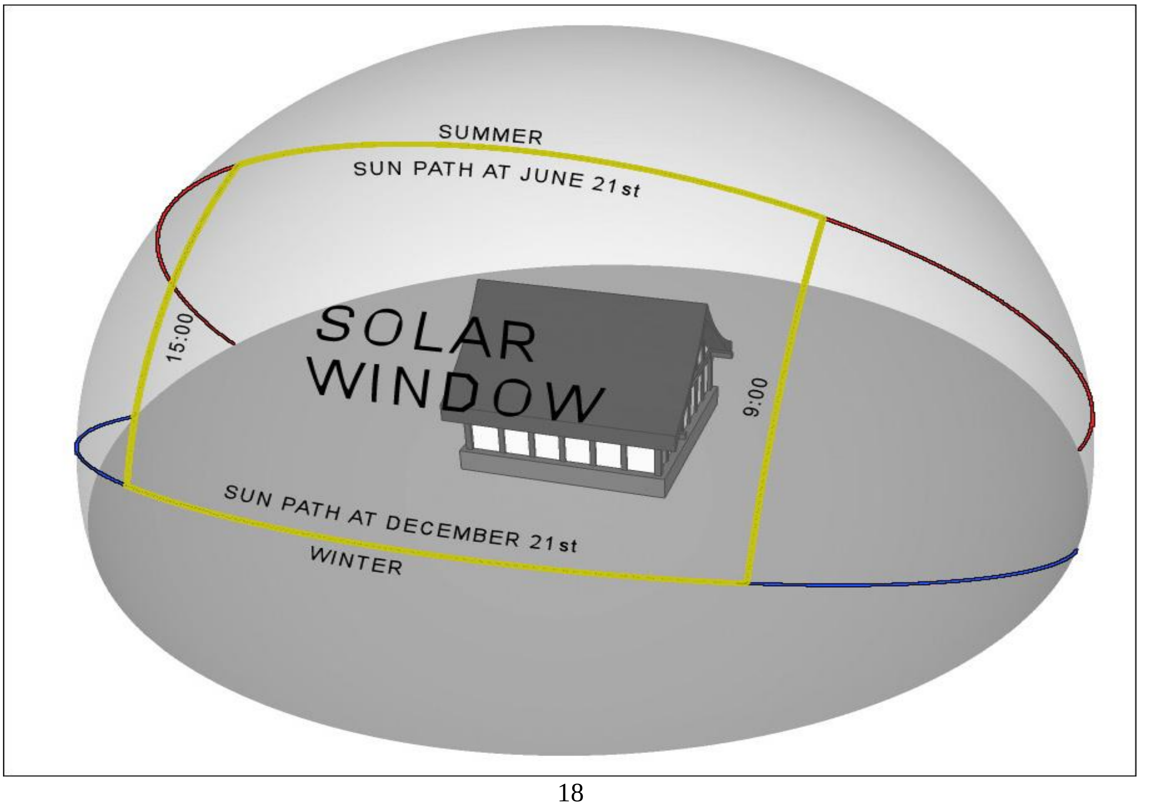
While urban renewal and construction projects are in a rise, the number of buildings using passive solar energy will influence future generations, for clean energy alongside the profit they provide.

3. SOLAR ENERGY USED IN BUILDINGS

Solar radiation reaches to the earth’s surface after passing through the earth’s magnetic field and atmosphere, solar. This amount of radiation is used by living organism and environment. Some portion of this received radiation is also reflected back to space from surface. Energy production systems of solar radiation, capture necessary amount of radiation that has reached the surface.

To capture the sun radiation, it is necessary to receive the sun at solar window. Solar window is an area marked in the sky dome between 9:00 and 15:00. The sun path follows in sky dome changes during a year. The highest and longest path occurs on 21 June, and the lowest and shortest path occurs on 21 December. If the sun’s position, marked at 9 o’clock in the morning in both dates, the sun will be somewhere on a line between those two points throughout the year as seen in the figure 3.1. Same line could be drawn in sky dome at 15:00 o’clock. The rectangle between the lines is called solar window.

Figure 3.1: Solar window



Applications that operate with solar energy, capture radiation in solar window with the sun ray altitude. Altitude of the sun rays coming to the earth changes according to position of the earth and the day of the year. Since Turkey is between 36˚ and 42˚ latitude, the sun rays reache approximately 33˚ in winter and 73˚ in summer. Total solar radiation in Turkey is 1400 kwh/m^2 at minimum and 2000 kwh/m^2 at maximum (Yenilenebilir enerji genel müdürlüğü, 2012).

3.1 ACTIVE SOLAR SYSTEMS

There are basically two main approaches in using the sun as a source of energy in buildings; active solar energy and passive solar energy. An active system generally concentrates on gaining heat through mechanical systems. Active systems work independently from buildings in contrast to passive systems. They are tools that buildings are equipped with. Main parts of these systems are the sun collectors and heat distribution units. Heat collectors generally are placed on the rooftops and are connected to distribution units via pipes that water or air circulates in. Installations could be equipped with heat storage units like rock beds or water tanks. Since active systems are based on mechanical systems, electricity is also used to activate fans and valves. Active systems need maintenance regularly, because of the mechanical parts. Though active solar systems work independently of the building itself, installations on post construction are possible. In this research active solar energy use in buildings is not examined due to the limitation of the thesis.

3.2 THE PASSIVE SOLAR SYSTEMS

Passive solar energy systems use the sun as the main energy source in buildings to heat up and cool down without using any conventional energy resources and advanced mechanical parts (Jones & McFarland, 1984, p. 1). The energy found in the environment is collected and used for heating buildings. In the passive concept, thermal energy streams in a building by natural ways such as radiation, conduction and convection (Mazria, 1979, p. 28). Components of the passive systems are the whole building or some parts of the structure, that work in collecting, distributing and storing heat. The passive solar systems, although known to have similar meanings with other previously mentioned environmental approaches, has differences from them.

The passive solar energy is based on certain rules and regulations of physics, geography and astronomy. Arguments and developments in passive systems are generally about building materials that could increase performance of systems. Secondly a passive solar building is manifested by the systems it uses. However it is possible to discuss the buildings that claimed to be environmental according to the used materials or emission levels in other concepts. A building that consists of completely natural elements cannot be a proof for being a passive solar design. A building that uses the sun as a main energy source for heating and cooling could be defined as a passive solar system. Finally passive system applications are done by lowest possible budget with intensions of keeping passive systems both desirable and profitable. By being economical in construction and with low maintenance fees, aim of passive systems is to spread out in mass applications and to create a habit on using solar energy. But some ecological concepts do not have a priority as being economic. They construct any application with any materials to reach targeted usage of solar energy regardless how high the budget is.

Adaptation of passive solar system into design operates with three main principles. They are layout principles, structural principles and efficient principles. The sequence of those principles is important and must be studied in following order in planning. All of those steps are extremely important in achieving a properly working solar passive structure, as every single principle and code works with the other as a chain reaction. Incorrect use of the principles could cause the system to collapse or decreases the performance.

Layout principle decisions are made according to site and geographical conditions. Design of the building is shaped to increase solar exposure with these principles. Structural principles are adapted into planning to collect, store and distribute heat. Systems are chosen, to be suitable for needs and design of the building. These decisions are essential for proper functioning of the passive systems. Finally, to increase the efficiency of overall design and protection of the used systems, precautions are to be taken.

3.2.1 Layout Principles

Layout principles are mostly the design codes that are applied in the preliminary design stage. While the form is shaped to provide needs and functions of the building, layout principles support design to make passive systems work, with consideration of environmental factors. They are essential for optimum performance of solar passive systems.

Layout principles are grouped under four main headings. These are selection of the site, orientation and form, floor layout, space and wall openings.

3.2.1.1 Selection of the site

The land must be investigated, whether or not it is appropriate for passive technologies. To construct a proper working system, assessment of potentials and problems are important. The usability and value of all areas on the site, management of the zones should be made according to principles, after planning of the settlement.

The sun is essential number one for passive systems to work. Having the sunlight during day time is an opportunity for the land. Most of the solar gains occur on the south face of a building, in the northern hemisphere. In winter, buildings should be exposed to the sun during solar window. The south should be inspected to avoid shading on the south face of the building. The south of the land should be free from trees, hills and other buildings to receive the sunlight between 09:00 and 15:00 o'clock as seen in the figure 3.2.

Figure 3.2: Open south

Winter winds coming from the north create a threat for the performance of the passive systems. Protection of building from winter winds is necessary for protection of the heat.

The north face of selected site should be sheltered with landscaping or by the earth sheltering as seen in the figure 3.3. This precaution reduces the exposure to north winds and increases the effectiveness of exterior insulation.

Figure 3.3: Protection from north

While designing outdoor spaces on site, the sunlight should be considered as well. Observations show that open spaces that have social purposes, are not used efficiently if they cannot receive the sunlight (Alexander, Ishikawa, & Silverstein, 1977, p. 55). Areas that do not receive solar radiation are destined to be occupied less than areas that receive enough solar radiation. Arranging outdoor social spaces at the south side increases amount of usage and provides comfort.

Selection of land and place of building affects directly the efficiency of solar passive systems. The simulations of the sunlight exposure may be done by manually using the sun charts and also done by using software programs.

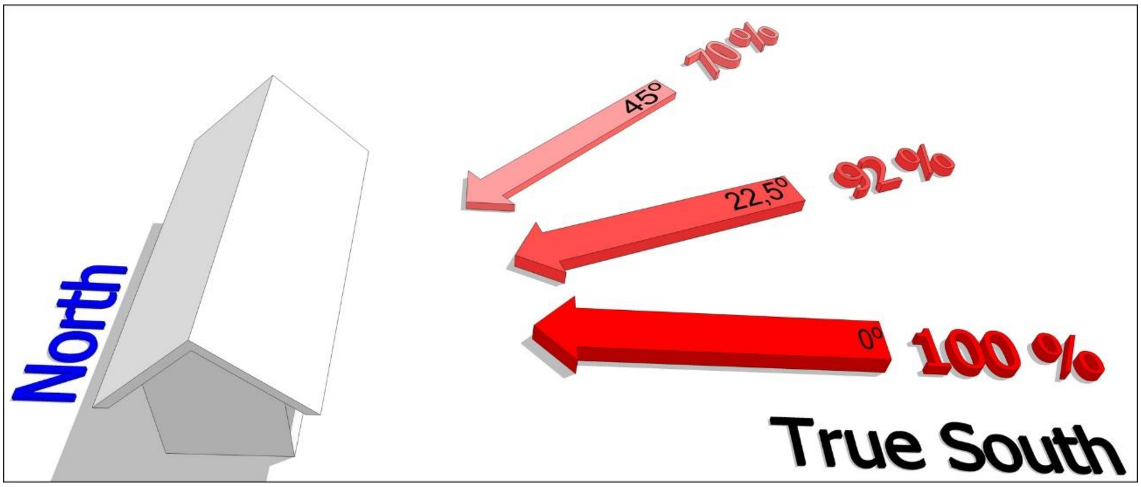
In addition, creating functioning north zones on the site depends on analyzed factors. If wrong decisions are made during design stages, it is almost impossible to make repairs after construction.

3.2.1.2 Orientation and form

Orientation and form decisions made in design stage, increase the strength of the building to exterior environmental factors, as well as they increase the performance of solar passive systems. Also when designing the building, considering north zones improves the usability of the land.

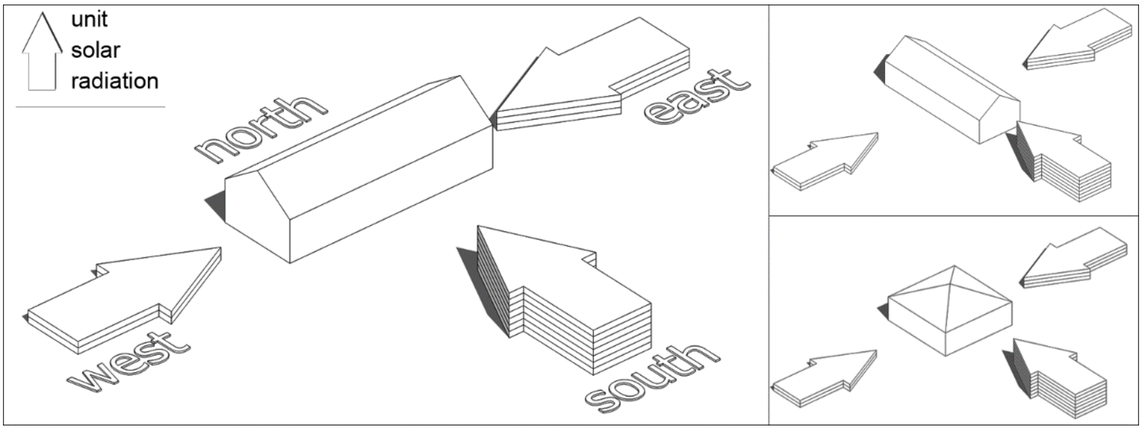
Orientation of the building, directly affects solar gain. To capture as much the sunlight as possible, building should face to the true south. The true south and magnetic south differs from each other. Magnetic poles slightly change with respect to years and geographical position on the earth (Myers, 2006, pp. 268-269). This is called magnetic declination. Deviating from true south reduces energy gained by solar radiation. For 22.5˚ solar gain reduces to 92 percent, for 45˚ solar gain reduces to 70 percent as seen it the figure 3.4 (Chiras, 2002, p. 21). For optimum performance of passive systems, building should face the true south as directly as possible. Failing to do this will increase the usage of backup heating to fill the energy gap.

Figure 3.4: Solar orientation



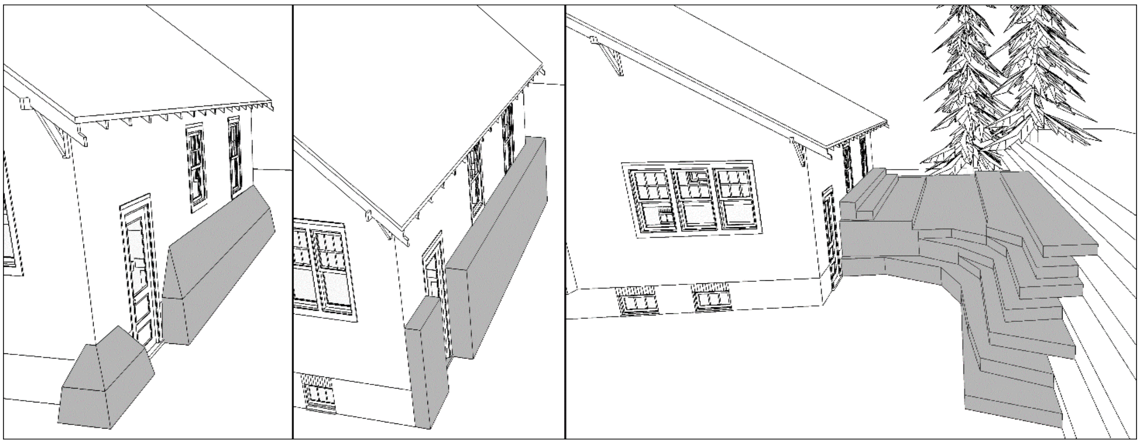
The form of the building maintains a control on solar gain. Since maximum amount of solar radiation strikes from the south, the south face of the building should be the long side. Research on the effects of climate on form reveal that square shape is not an efficient form for any climate and south-north elongated form is less efficient than a square shape (Olgyay & Olgyay, 1963, pp. 54-62). The optimum plan shape is east-west elongated form, in order to gain maximum solar radiation in winter, as seen in the figure 3.5. East-west elongated form is exposed to longer solar radiation on south face in winter. In east-west elongated form, east and west are the short sides, thus the solar gain is at minimum in those sides. In summer when heat is not wanted, this form protects the building from gaining heat in sunrise and sunset (Olgyay & Olgyay, 1963, pp. 54-62).

Figure 3.5: Building forms



By using form and environment together in design, impacts of the sun and air could be managed to avoid fluctuations at indoor temperatures. The north wall of the building could be buried under soil, if there is a sloped site for protection from north winds in winter. If there is no slope on site, ground could filled to lean on the north wall with creating a small slope or a secondary ground wall, as seen in the figure 3.6. Also, low sloped roofs will reduce the effects of winds by allowing them pass through.

Figure 3.6: Earth sheltering



The north sides of the buildings are colder and darker compered to the south side. This fact could cause in decrease of usage and value of the north zones. To protect the north side from winter winds, evergreen trees could be used on the north side. Low rise buildings cast less shadows on the north side. Using reflective surfaces on north, increases the light levels. Those precautions help to increase the use of exterior spaces at the north side.

3.2.1.3 Floor layout

Interior spaces are shaped by the needs of the users and function of the building. Also interior space organization is important for passive systems with the intention of protection from winter cold. Interior layout is designed from the south to the north starting with the most used spaces to lesser occupied spaces as the basic regulation for protection.

In passive design, a house is separated into two groups', living spaces and buffer zones. The least occupied spaces like stairs, corridors, closets, laundry rooms, garages are called buffer zones and used to keep cold away from living spaces (Woodner, 1999, p. 56). So they are placed to the north side of the building. Living spaces are placed to south east, south and south west depending on their needs of heat and natural light.

The north side of the building is the coldest and the darkest during the winter. The south side, on the other hand, is three times brighter and hotter than east and west sides of the building. By the organization, the most utilized spaces are positioned to the south to receive direct heat and light from the sun.

While designing living environments in the south side, to keep comfort levels and to prevent excessive heat and light, some precautions should be taken. Putting thermal storage walls to some windows on the south can control heat and light.

While considering indoor spaces, planning a secondary mid buffer zones with entrances of buildings protect heat losses from entrance and exit.

3.2.1.4 Space and wall openings

Windows are the source of heat and light during winter. Random placements of windows and irrelevant sizes create energy drain in winter. For passive buildings window's sizes, places and kinds should be picked according to energy required.

According to building orientation, the south side of the buildings is exposed to three times more solar radiation than the east-west side. To gain maximum amount of radiation windows should be concentrated on the south face. Since east west solar radiations are considerably less, keeping window sizes and quantities at minimum is an energy efficient precaution. Using double layered windows also help for better insulation on the east west sides. The east and west sides of the building only face the sun for a limited time during a day, they become the source of heat drain except that limited time. Since the north side cannot catch the sunlight, all the windows on the north side always drain heat in the southern hemisphere. Usage of movable insulations protects heat loss when the sun is not up in the sky dome.

3.2.2 Structural Principles

Structural principles are referred as building parts that specifically developed for catching solar radiation, converting solar radiation into heat energy and storing energy. All structural principles have different concept in processing solar radiation. Building's function and design are key factors in choosing the adequate principles. To benefit more from the sun, after applying layout principles, structural principles could be included to design. Every single system comes with some design limitations and opportunities. Choosing a heating system should be according to requirements of each space. Structural principles are studied with three main characteristics according to their concepts in using solar radiation. They are direct gain, indirect gain and isolated gain, as seen in the table 3.1.

Table 3.1: Structural classification of gain type

STRUCTURAL PRINCIPALS	Direct Gain	Indirect Gain	Isolated Gain
Solar gain windows	X		
Clerestories and skylights	X		
Heat storage	X	X	
Exterior thermal walls		X	X
Sunspaces		X	X
Roofponds			X
Sun control		X	X

In direct gain, collection, conversion and storage processes of solar radiation occur in living spaces. Solar radiation is collected by the south facing openings in the building and those openings are directly connected to living spaces. The heat is converted from solar radiation via glazing of the building and indoor spaces are heated. If heat is needed for the night time, necessary amount of heat gained by solar radiation is stored in thermal masses that are placed in relation with the south openings. To obtain a habitable interior environment, all elements of direct gain systems should be designed and used in harmony. Main direct gain systems are; solar windows, clerestories - skylights and interior thermal storage walls.

Direct gain systems are conventional architectural elements that specially developed to gain, store and distribute energy. Budget of a project is not affected with excessive costs while designing a building that use direct gain systems. But past fitting the existing building with this system is very difficult and expensive. Because these systems require heat storage walls and floors with large openings on facade in order to operate.

There are specially designed compact structural parts for processing solar radiation into heat energy, also storing and delivering that energy gained from thesun. Indirect system consists of three main sections. Primary section collects solar radiation and converts it into heat energy. This component works with the same principles of solar windows (direct gain windows). Secondary section is the gap where converted heat energy is trapped. This gap is an isolated space from interior. The trapped heat energy could be either stored directly in thermal mass or could be released to interior spaces by small holes for increasing the temperature. The access of the heat from this gap to building is obtained with radiation and/or convection. The other function of this gap is to create a buffer zone between the building and exterior weather conditions. According to the design and chosen materials, the gap might be unnecessary. For those occasions thermal mass (heat storage) is built after solar collector without a gap. The final section of the indirect gain system is the thermal mass. Thermal mass is exposed to solar radiation directly during the sun time to store heat. This stored heat is used for heating during day and night. Thermal mass operates similar to thermal storage walls in direct gain systems. Briefly, indirect gain systems are compact structural parts that work closely with each section and are separated from interior spaces of the building.

One of the disadvantages of indirect gain systems is that they may block the view and daylight (Levy, Evans, & Gardstein, 1979, pp. 70-81). Also windows which are applied to thermal mass to gain daylight and some direct gain, reduce the performance of thermal mass. Thermal mass is exposed directly to window thus exposed directly to winter cold at night times. To protect the heat gained during day, solar radiation collectors used in indirect gain systems must be isolated from outside with movable insulations, also using double glazing windows are suggested (Levy, Evans, & Gardstein, 1979, p. 79). Indirect gain systems are more available for installations in existing buildings. Since only the south walls are modified to meet requirements.

Attached sunspaces are studied under indirect concept although they are not completely indirect but a combination of direct and indirect systems. Isolated gain has a unique and independent system. This concept receives radiation and stores heat remotely from the general structure of the building. Later this unique structure of isolated gain is combined with the design of the building. Although isolated gain is a unique concept, it follows the same rules of physics as others. After solar radiation is gained through glazing, it is stored in thermal mass. A primary convective loop is created between glazing and thermal mass. This loop helps to store heat as long as the sun is up. Thermal mass later is used for heating in building with a secondary convective loop. This secondary loop is created with ducts. If necessary, some fans could be used in ducts to increase efficiency.

All the concepts have their own advantages and disadvantages. There is not a specific concept to fit for all building types and all geographical conditions. Designer should have the knowledge of all the concepts with their strength and weaknesses to apply the most suitable one. To choose most efficient concept for building, the function and heat necessities of the design should be evaluated. If it is required, different systems and concepts could be combined to increase the performance. Performance is also could be increased with the right choice of the building materials.

The selection of building materials affects passive performance of the building. The usage of biodegradable and low energy-consuming materials is suggested for efficiency and for making contribution to environmental awareness. Thermal mass materials should be preferred according to their heat capacities. Choosing locally produced qualified materials as well minimizes the money and energy on transportation while supports local labor market.

3.2.2.1 Solar gain windows

Solar gain windows act like solar radiation collectors. The most known characteristic of a direct system is the large sized window facing south. Radiation received from solar gain windows is transformed to heat by furniture and structural elements in the building.

Windows sizes must be calculated carefully, since they are the source of solar radiation in winter. Smaller sized windows become insufficient to heat up the building during winter. Although oversized window causes excessive heating problems in summer.

Choosing right window area avoids low temperatures in building during most of the winter. For cold climates that have winter average temperatures below 0 to -7 °C, should be prefered a window area of temperate 0.2 – 0.4 m^2 per m^2 space of floor area. Although climates having winter 0 to 8 °C, should pick a window area of 0.1 – 0.2 m^2 per m^2 space (Mazria, 1979, p. 119). Those ratio of areas provide enough solar absorption for living spaces to receive 18 – 22 °C of indoor space temperature (Mazria, 1979, p. 119). Those numbers are for residential uses, but they could be applied to other building types with similar heat requirements.

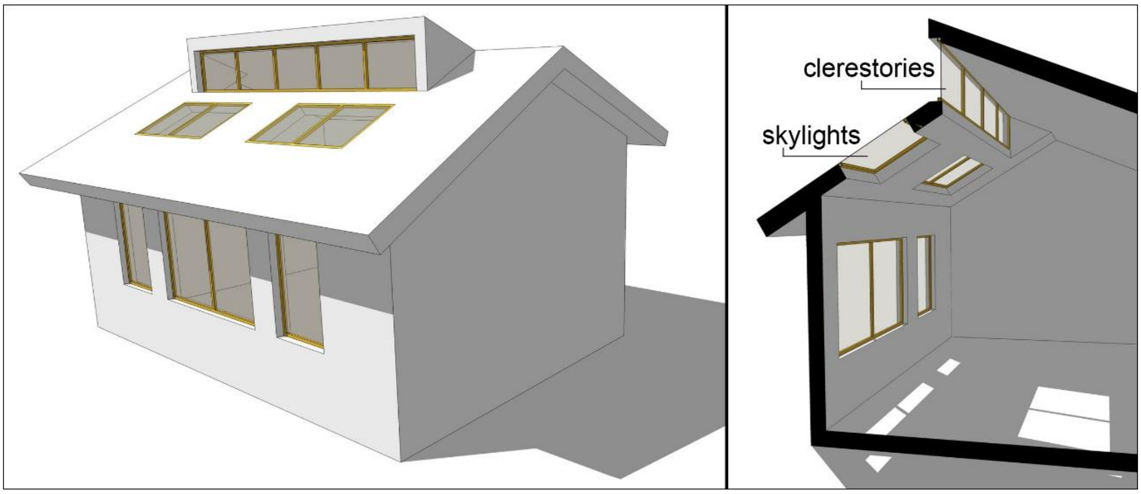
Window glazing choice and frame also affect the indoor temperature. Double glazing windows transmit almost the same radiation while protecting indoor temperatures. Using double glazed window is suggested for all climate conditions. However, using triple glazed window is only suggested for severe climate conditions. Window frames are also an important factor. Application of windows must be done properly to prevent cold weather entrance from joint points. Choosing frames with air traps inside also increases protection from cold. Since solar windows are always exposed to exterior condition, excessive strike of cold air at night times occurs via those large openings. To prevent this, movable insulation could be used.

The solar window systems do not change the general appearance of the building. Only with an extra small amount of budget, it could be applied in construction process. Besides having a large window opening increases the natural light and view. On the other hand, furniture that are exposed to the direct the sunlight will fade by time. Large window openings with no curtains could create privacy problem. If a movable insulation is applied to windows, operating twice a day could create disinclination.

3.2.2.2 Clerestories and skylights

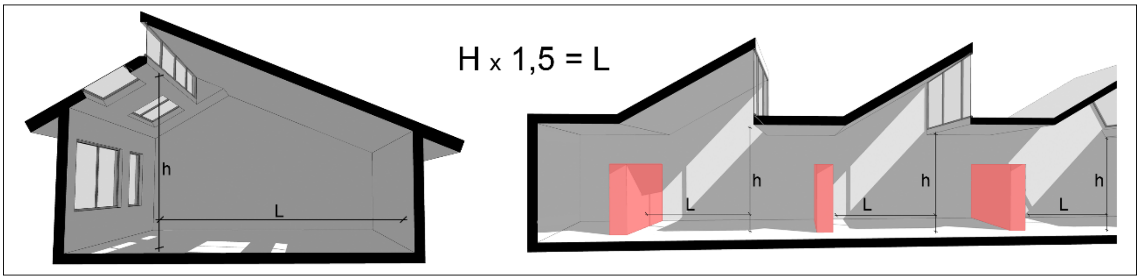
According to the needs and functions of building roof openings could be used as a direct gain system. South facing clerestories and skylights could function as solar radiation collectors, as seen in the figure 3.7.

Figure 3.7: Clerestories and skylights



Radiation gained by roof is distributed to open space or an interior surface. If a thermal storage wall is positioned against roof openings for direct exposure of sunlight, the distance between roof openings and thermal wall should be 1.5 times more than the height of roof openings from floor as seen in the figure 3.8 (Mazria, 1979, p. 128). Thermal storage walls need to receive solar radiation directly through glass with vast distances, otherwise thermal stage walls do not work efficiently.

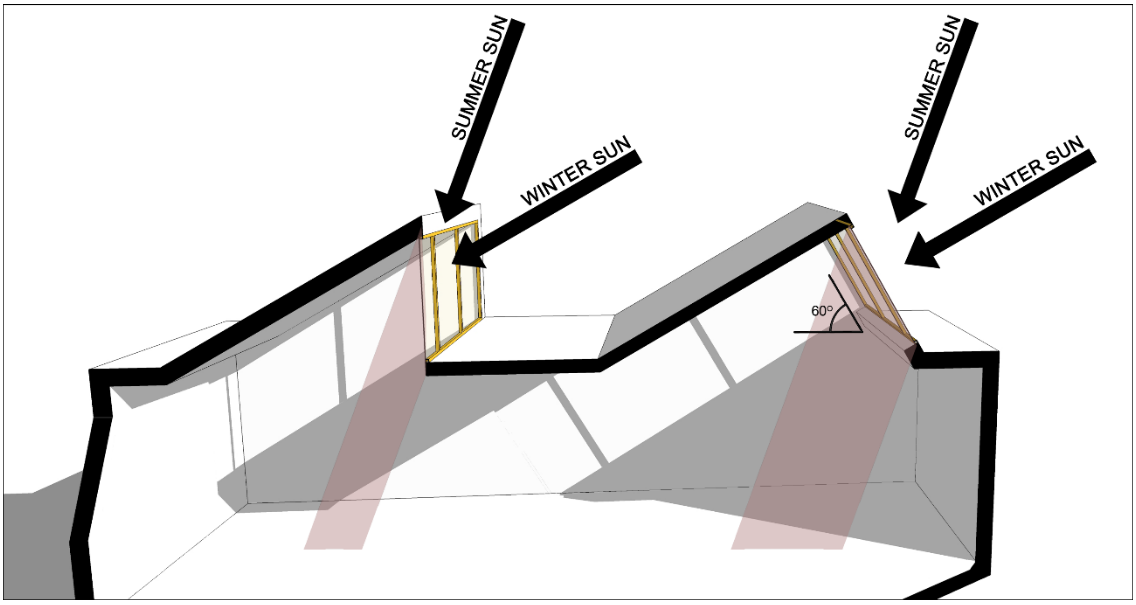
Figure 3.8: Maximum length for solar wall



The size of the roof openings could be calculated by the same formulas in the solar window principles. There are differences between the amounts of radiation gained by a tilted and vertical opening. The optimum radiation is gained by a 60º opening in winter (Mazria, 1979, p. 129). In winter vertical windows operate with close efficiency in relation to windows with 60º openings, but they receive less radiation in summer, when the sun rays reach the earth with high angle, as seen in the figure 3.9. Openings with tilted angle receive more solar energy in summer and cause excessive indoor temperatures.

Adding movable insulation to roof openings prevents high interior temperatures in summer and loss of heat in winter nights.

Figure 3.9: Window angle



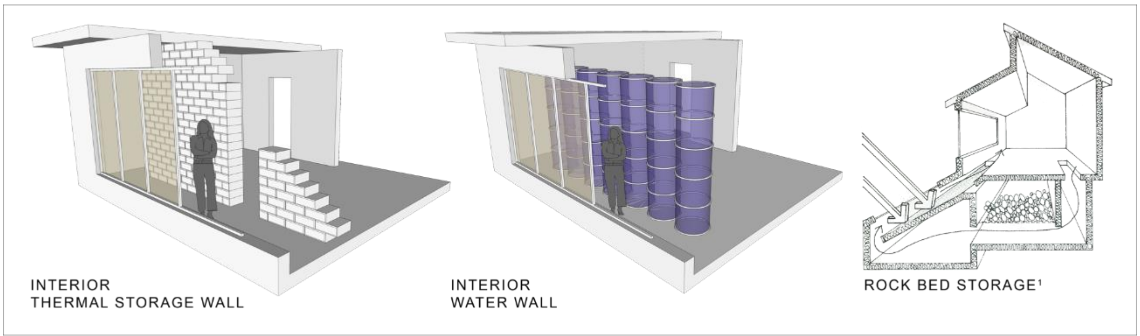
Roof openings and roof itself could be designed in different forms to increase the energy gained from the sun. The surface of the roof works as reflector for clerestories. Using bright materials with high reflective capacity or direct use of reflectors on roof increases the radiation gained through roof openings in winter.

Using clerestories and skylights, the sunlight enters the building from top side of the space. Diffused light causes an equal illumination all around the space, preventing glare problems and bright interiors. Receiving the sunlight from top of the space has other advantages. Certain fabrics and furniture are faded in time by exposed of the sunlight, but receiving the sun from above protects fabrics and furniture. Using roof openings as direct gain systems assures privacy since windows on the facade are no longer used for capturing the sunlight.

3.2.2.3 Heat storage

Direct, indirect and isolated gain concepts can heat up the building during day time. However to keep the warmth all along the night till the morning and to keep temperature fluctuations at minimum, some of the heat gain must be stored. Floors and walls could be used to store heat. For an optimum passive performance, those elements should have some physical and structural features. If necessary, private walls or even other materials could be used in place of structural elements. Private interior and exterior walls, water walls (trombe walls), rock beds, even chemical components could be used for thermal storage purposes as seen in figure 3.10.

Figure 3.10: Heat storage examples



Source: 1 M. Emanuel Levy, (1983) The passive solar construction handbook, Rodale Press, p.169

Materials for absorption and storage are two vital components in storing heat. The south facing surface of the storage component is called the absorber component. When solar radiation and heat strike a surface, an amount of this radiation is reflected back while remaining energy is absorbed. Absorption is a ratio of absorbed radiation of the total received radiation on the surface of an object (Asm Committee, 2002, p. 526). For an efficient storage, the surface material should have high absorption ratio. Also ability of emissivity effects overall performance of absorber. Emissivity is an ability to emit an amount of energy gathered from exterior (Asm Committee, 2002, p. 524). Emitted amount of energy cannot be used or stored by the passive system. Thus, for an efficient absorber surface, low emissivity is required. The physical properties like color and surface texture are important as characteristics of material. Light colored surfaces have high reflection ability and dark colored surfaces have high absorption ability. Dark colors have the absorption ratio of 90 percent and light colors could be low as 30 percent (Balcomb, et al., 1980, p. 186). Therefore dark colored surfaces increase the performance. Area of the absorber surface is another parameter that effects the performance. Using rough textures on surfaces increases the area as well as the absorption.

Properly designed surfaces allow large amount of heat energy to flow through the system. Storing heat energy with low budget is important as much as the effectiveness of the system. Using reinforced concrete or masonry has a potential. They could be used as structural components and heat storage units. This opportunity minimizes the cost of having a thermal storage. Thus reinforced concrete and masonry are the most popular elements for heat storage units. But for structural and storage purposes different materials could be used. While designing a thermal storage, heat capacities of the materials should be considered, since this ability has a vital importance in storing heat energy. Heat capacity is quantity of heat given to the substance to increase its temperature by one degree (Hansen, 1995, p. 12). If a material has a high heat capacity, it can store more energy when increasing its temperature. Thus materials with high heat energy capacities are better for storing heat energy. The ability of conductivity is also a feature to consider. High conductive materials heat and cool very fast. In contrast, very low conductors almost never transfer heat and they are used as insulation materials. Conduction should not be too fast or too slow, it should be balanced to store the heat during the day and release it back to the building during the night. Concrete, brick, adobe, wood and other building materials have different heat capacities and conductivities as seen in the table 3.2. The cost of application, transportation and maintenance should be considered before choosing a material.

Table 3.2: Characteristics of building materials

MATERIAL	HEAT CAPACITY (kJ/m^3K) 1	CONDUCTIVITY (W/mK) 2	DENSITY (kg/m^3) 2
CONCRETE	2016	0,5	0,5
BRICK	1612	1,08	1,08
ADOBE	1300	1,25	1,25
WOOD	806	0,078	0,078
WATER	4184	0,58	0,58
GRANITE	2419	2,3	2,3

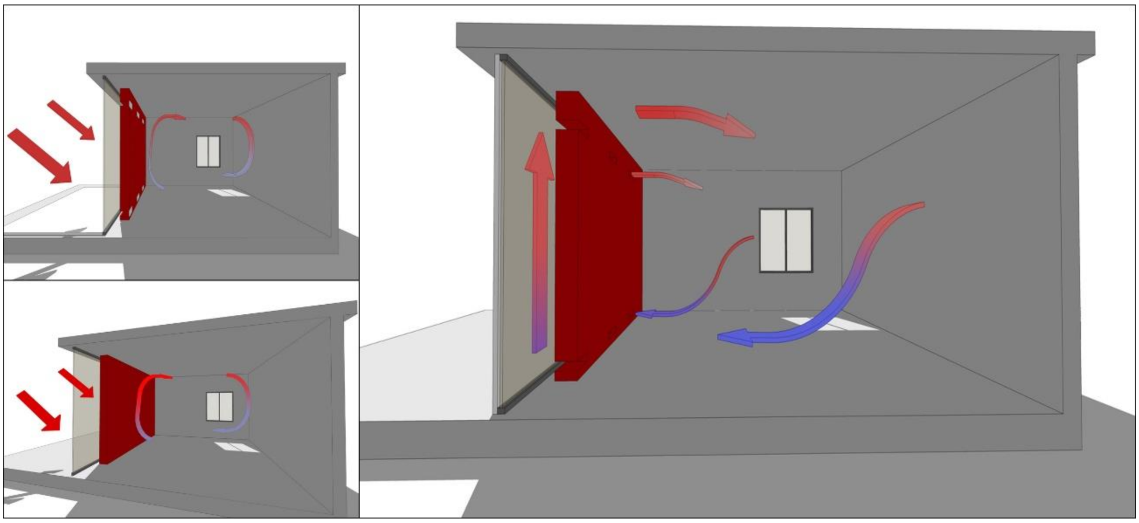
Source: 1 Steven V Szokolay, (2008) Introduction to architectural science: the basis of sustainable design, Elsevier Ltd, Burlington, p.96,97
2 Fiona Cobb, (2009) Structural engineer's pocket book, Elsevier Ltd, Burlington, p.333

3.2.2.4 Exterior thermal walls

Exterior thermal wall system, known as barra-costantini wall, is a passive solar compact system in a place of an exterior wall. It is possible to use exterior facade as a combined system for receiving - transforming solar radiation and delivering - storing heat energy.

In this compact, concept solar radiation is received through transparent surface like glazing. While passing through the transparent surface, solar radiation is trapped inside the system and transforms into heat. It is important for heat energy to reach thermal storage without any layer of materials between glazing and thermal mass. The surface of the thermal mass should be designed to receive and absorb as much heat energy as it can. According to the interior building conditions and functions, the efficient materials should be picked. Variety of the materials changes from liquids like water to solids like adobe or concrete. Even chemical materials could be used. The same studied details on thermal mass could be applied for heat storages of exterior thermal walls. For different system settings, trapped heat could be either directly stored by heat storage units or let free for ventilation by convection in space while it is stored in thermal mass as seen in the figure 3.11.

Figure 3.11: Exterior thermal wall

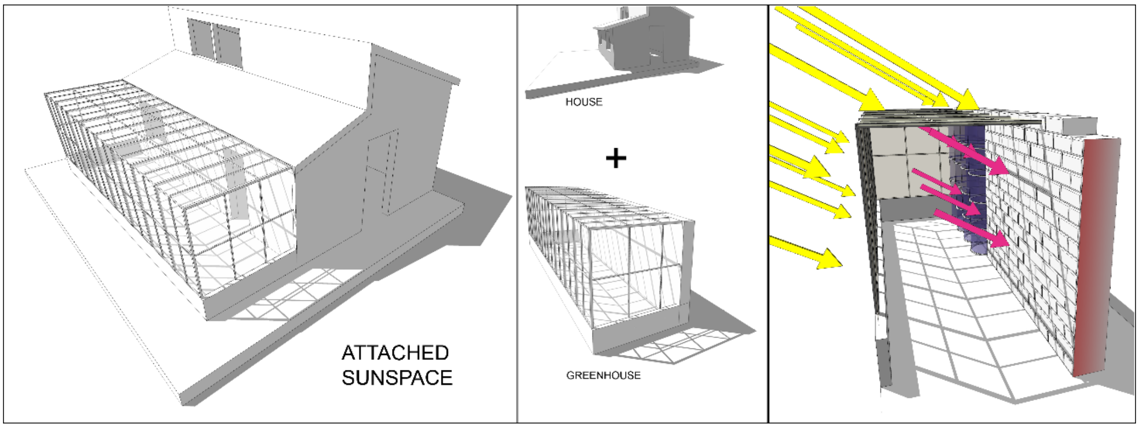


The exterior thermal wall system has advantages and disadvantages as well. Applications on post constructions are possible, and cheaper than having a post constructed direct gain system. Since there is no thermal mass inside the building, interior spaces are flexible. Having a direct wall at the facade prevents any harmful effects coming from the sun like; interior glare effects, fading of furniture. Since window sizes are limited, privacy is much easier to protect. Since exterior thermal wall system consists of a wall on the facade, it limits the view and daylight coming from outside. Placing holes on the thermal mass for daylight and view maybe even for some direct gain from the sun decreases the performance of the system.

3.2.2.5 Sunspaces

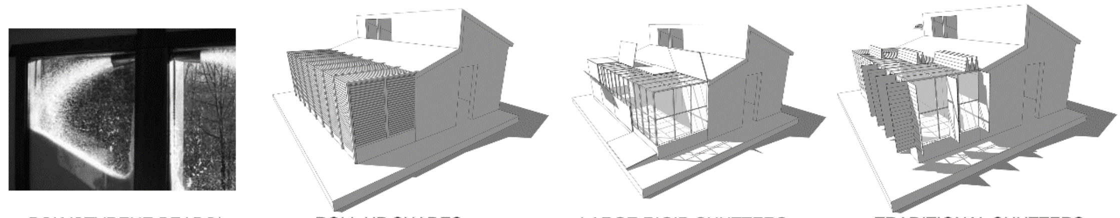
A sunspace is an exterior room covered with glazing and located on the south side of the building. These structures could be built as a part of the original design of the building as well as they could be added to building as a past fit. Thus sometimes they are named attached sunspaces. Sunspace has similarities with greenhouses and solariums. They are the separated spaces where solar radiation is collected, stored and distributed as seen in the figure 3.12.

Figure 3.12: Sunspaces



Sunspace transforms gained solar radiation into heat energy by glazing. The position of the glazing effects solar absorption. The most solar gain occurs when angle of incidence is 90 degree of glazing. Since sunspace is completely covered with glazing, temperature is extremely high when the sun is up and extremely low at night. So constructing sunspace without a separation wall between building space, creates high degrees of temperature fluctuations and uncomfortably hot interiors during the sun time. Insulating glazing against cold at winter night is among the measures to be taken. Insulation could be with large rigid shutters, traditional shutters, polystyrene beads, roll up shades as seen in the figure 3.13. Choosing an easy system with low maintenance requirements to operate is important, since opening and closing the insulators is a daily task.

Figure 3.13: Window shutters for sunspaces



Source: 1 http://resvent.files.wordpress.com/2013/08/cwbead4.jpg?w=450, 24.december.2013

Also, to reduce temperature fluctuations and to create habitable interior in sunspaces constructing a thermal storage wall as a separation is highly recommended. Interior of sunspace could be used to serve different functions like; a greenhouse, a teahouse or a storage area. In any case, placing a barrier between thermal storage and glazing decreases the performance dramatically. The thermal storage could be constructed as a wall, a trombe wall or even a rocky bed according to the design. The separation wall between the sunspace and building acts like a valve. During the sun time, heat flow could be provided via operating doors, windows and vents that constructed in the separation wall. Also heat flow can be provided by specially designed ventilation holes to create a circulation system via convection all around the building.

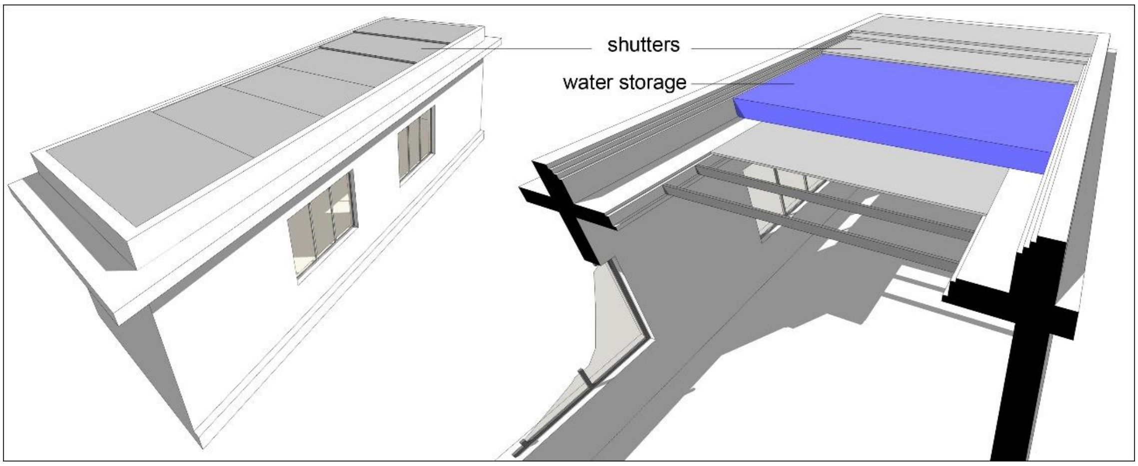
Sunspace is a complete structural unit that could operate separately without the building. Attached sunspace is the largest concept when comparing with other structural principles. This fact generates many advantages and disadvantages. Sunspace is large enough to maintain different concepts for heat storage and solar gain systems within. This complex design could increase the overall performance. The length of sunspace could cover two floor together. This could be an architectural attribute in design while creating a unified air flow system. Post construction is possible in one and two floor buildings. On the contrary large buildings have disadvantages like insulation, heat loss and difficulties in constructing for three or higher floor buildings. In sunspaces glazing is much more than in other concepts, so isolating all glazing area could be hard to perform every day and using electric powered machinery could bring high maintenance costs. Since insulation is vitally important for passive systems, failure in insulation will prevent heating at nights, also overall system performance could evidently drop. Having an additional interior space is an additional space to heat up at winter nights.

3.2.2.6 Roof ponds

Roof pond is a compact solar passive system. All constructions and systems take place on the roof. This concept uses water as a thermal storage material, as a result of being the cheapest and the most efficient material to use in a passive systems. This features are the most distinctive characteristics of roof pond system.

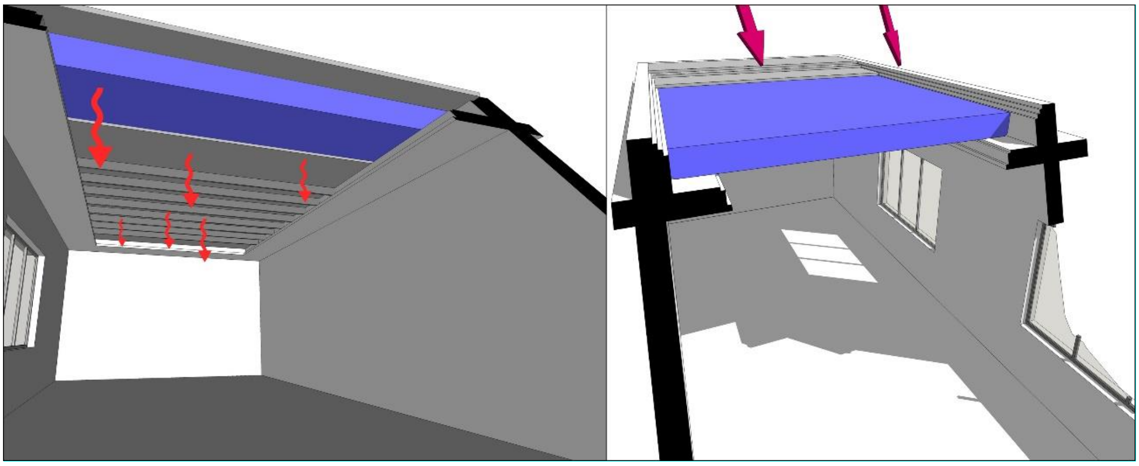
Passive operations like colleting solar radiation, storing and delivering heat, occurs on the roof. While for mild climates, it is possible to choose between flat and sloped roofs, but for cold climates the sloped roof is suggested. The interior space of sloped roof acts as a barrier for cold winds that strikes in winter, but for mild climates such protection might be unnecessary. To protect stored heat from cold, shutters are needed in design of the roof as seen in the figure 3.14. Received solar radiation is collected by the roof surface. To have collector surfaces, large openings like windows are needed on the roof. Openings on the roof, should be covered with glazing or other materials to collect radiation and trap the heat inside the roof. Water is placed in containers as thermal mass to store and receive direct heat from roof openings. Heat transfer between water storage and building occurs with conduction as seen in the figure 3.15. The construction of the slap that holds the water storage above interior space, should allow heat transfer between the space and storage. Choosing materials with minimum insulating abilities for the layer between roof and interior increases the performance of the system. Since water storage creates an extra weight on the roof and load bearing system, this extra weight must be considered in structural design of the building.

Figure 3.14: Roof pond structure



In roof pond systems thermal mass is located on the roof and at the top of the interior. Thus roof ponds become an efficient cooler for hot summer days due to the convection.

Figure 3.15: Heat transfer in roof ponds



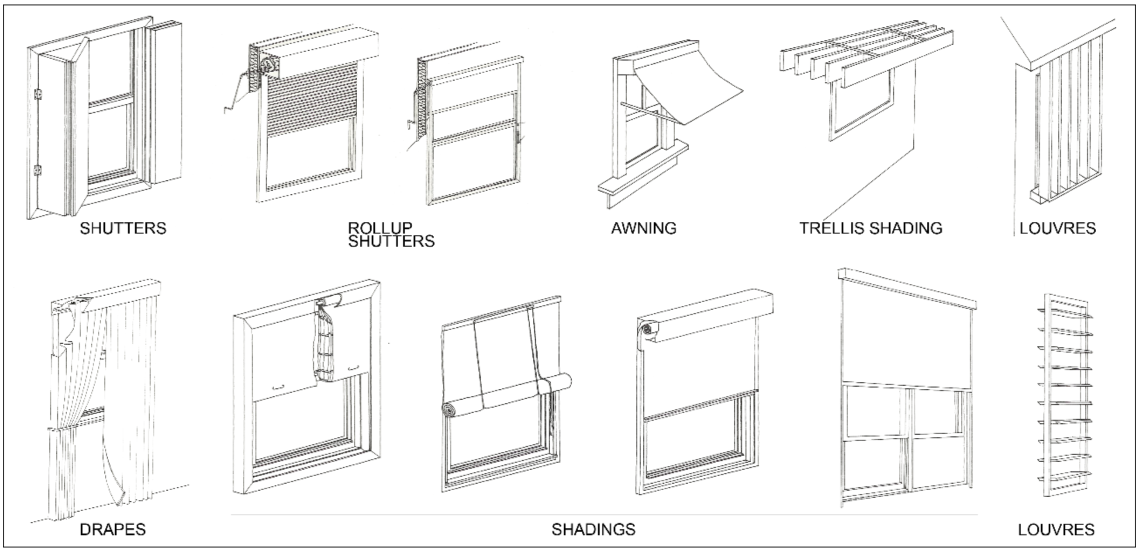
Having solar passive system on the top of building has some benefits. Roof ponds are designed on the roofs, thus the overall design of the building is not modified to receive maximum solar gain. This approach has minimum effect on design. Since thermal storage and collectors are on the roof, interior space could be used more freely than with other concepts. Roof pond cools the roof and building from top. This is an efficient way for cooling in summer. This physical advantage could cause winter heating to work under performance. To overcome concentrated hot air above and on the ceiling, extra design parameters should be added to design like openings on ceiling or ventilation holes. A roof based system has handicaps as well as its benefits. First of all, roof ponds are not suggested for cold climates. To use them in cold climates, extra reflectors and insulations are needed. Being on the top of the building reduces and minimizes the relationship between lower levels of the building and thermal storage. Without another solar passive system installed, roof ponds are not suggested for application on multiple story houses. The necessary amount of water to heat entire space beneath the roof is extra load for structure, so applications on post construction are not suggested.

3.2.2.7 Sun control and cooling

For most of regions around the world, winter colds are the top priority for protection. Solar passive systems are largely focused on heating in winter. Passive solar systems could be used for cooling in summer with some precautions and design principles. There are two different summer climates according to weather type. Dry hot and humid hot climates. In dry hot climates, nights are much cooler than day time and main source for heat is the sun. On the contrary, for humid hot climates, weather does not get much cool at night and the main reason for heat is the weather.

For dry hot climates, to block the direct summer sun has a vital importance. In summer, the sunlight reaches the earth with steeper angle than in winter. Using shade devices or architectural components to shade on windows provides shelter against the direct sunlight. There are different architectural designs to protect from the direct sunlight as seen in the figure 3.16. The summer sun delivers excessive heat where it strikes. Roofs and walls that exposed the sunlight, get heated up. And if exterior of the building is not properly insulated, that excessive heat passes through the roof and walls. Also using light colors on roofs and exterior walls minimizes the absorption of solar radiation. To control the environment with landscape also helps to reduce summer heat as studied in layout principles. Passive systems could operate for cooling the building in summer. To perform adverse effect in winter, thermal mass should be protected from the direct sunlight and exposed to cool air of summer nights. Thermal mass stores the coolness to release it at noon.

Figure 3.16: Shading devices and sun shelters

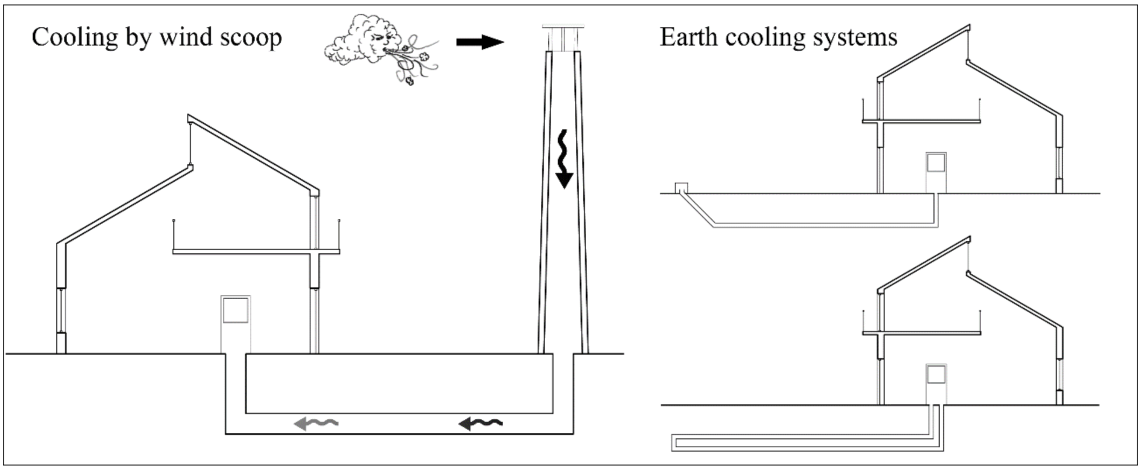


Source: M. Emanuel Levy, (1983) The passive solar construction handbook, Rodale Press, p.24,251,252

Protection against humid hot climates is challenging. Even if the all precautions are taken it is not possible to cool down the house. In humid hot climates weather does not get cooler in night time or at shades. For such climates, ventilation is suggested to vent the heated interior air. To keep interior temperature comfortable, all heated air inside the building should be vented. Ventilation the building from one side to the other is called cross ventilation. For an effective cross ventilation the gaps are needed on both side of the building. Windows could be used as ventilation openings. For a high performance of ventilation in the buildings, gaps should be designed according to the wind directions on the site. For further cooling in humid hot climates passive technics like wind scoop and the earth cooling could be used. The earth temperature drops lowers as it gets deeper, and these systems use underground coolness.

Winds scoop takes advantage of winds in higher altitude. A chimney tower higher than building catches the wind. The shaft in the chimney is connected to building through underground tunnel. Trapped wind in the chimney pumps the cold air in the tunnel to the building as seen in the figure 3.17. The earth cooling system works almost the same way without a chimney. Open and closed pipe concepts are two main approaches to the earth cooling as seen in the figure 3.17. Pipes installed underground allow air to pass through, while underground soil temperature cools the air. To reach adequate air flow, electric powered fans could be added to system.

Figure 3.17: Cooling systems



3.2.3 Efficiency Principles

For passive systems to operate with optimum performance and for building to be worked efficiently, there are cases that have to be cared in design and construction stage. Construction stage of the building has to be monitored to eliminate any poor workmanship and applications. Proper insulation is one of the top priorities for sustainability. Selection of materials, maintenance, shading, reflectors, cloudy day storage and planting are other cases to be considered while designing and constructing a solar passive building. In this study, topics of insulation, reflectors and backup heating have been taken in consideration.

3.2.3.1 Insulation

The aim of the passive system is to be sufficient for heating requirements of the building without the need of secondary heating system. To reach this aim, protection of the interior has a major importance. Hence passive concept operates with extra isolation for protection (Chiras, 2002, p. 31).

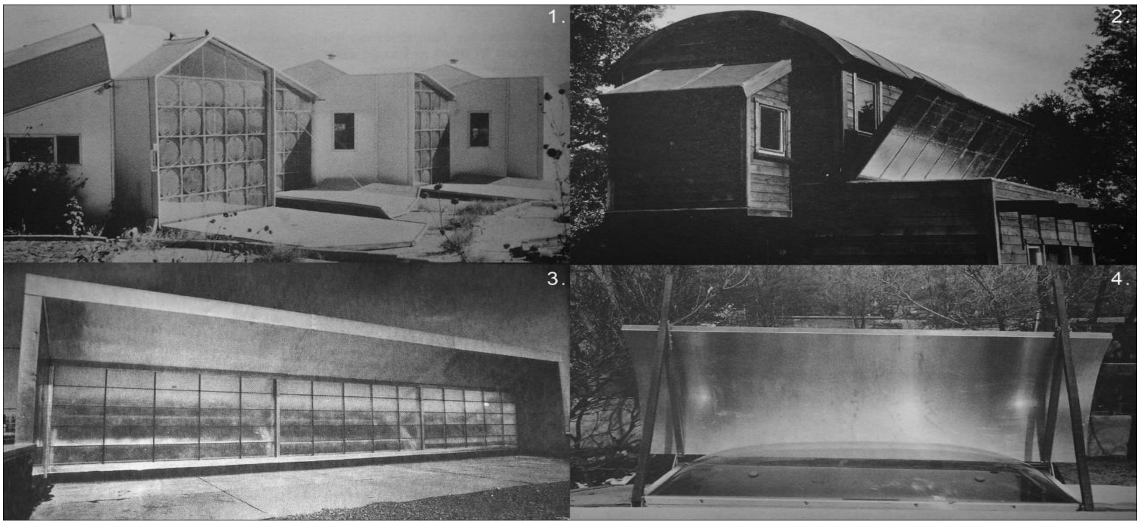
For an efficient protection, isolation should be applied on the exterior walls of the building (Levy, Evans, & Gardstein, 1979, p. 249). But exterior isolation exposes to physical conditions of winter. So conserving isolation against the cold, rain, snow and frost is vital for keeping passive systems operational. Protective layers must be applied on the exterior isolation. For cold climates a secondary wall could be constructed after isolation as a protective layer and to increase the effect of insulation. Insulation of floor, roof and foundations is important as insulation of exterior walls. Thus to have an optimum performance of passive systems in the building, insulation must be done completely. Also yearly maintenance should be carried out.

3.2.3.2 Reflectors

Passive systems use solar radiation to gain heat. There is a direct proportion between gained solar radiation and produced heat. Thus buildings get heated as much as the sunlight they receive. Using larger window area for increasing the heat gain affects interior heat control, efficiency and the budget. But received solar radiation could be increased without constructing larger windows.

Light colored surfaces reflect light and they could be used to gain more sunlight through windows (DeKay & Brown, 2014, p. 103). Reflectors could be designed in many different ways. For ground floors, the space in front of the window could be filled with light colored landscape components to increase the reflected sunlight as seen in figure 3.18. Window shutters could also used as reflective surfaces as seen in figure 3.18.

Figure 3.18: Sunlight reflectors



Source: Edward Mazria, (1979) The passive solar energy book, Rodale Press, p.52, 132, 191, 240

3.2.3.3 Backup heating

It is necessary to add a non-passive back up heating system to passive designs, despite its energy efficiency. Backup heating systems are insurance, for the winter days that are unusually colder than average days and for cloudy days.

When choosing a backup heating system information about the required heat for the building and alternative heating systems should be gathered. Occupancy of the building according to the function, number of unusually and extremely cold days below winter average, number of cloudy days in winter are basic criteria to choose backup heating system. Information about heating systems is necessary to choose the most adequate system. General features are given in table 3.3 for common backup heating systems.

Table 3.3: Comparison of backup heating systems

COMPARISON OF BACKUP HEATING SYSTEMS

TYPE	RESPONSE TIME	RENEWABLE FUEL	POLLUTION	CAPACITY	COMFORT LEVEL	EFFICIENCY	COST	RANK 1-10 (1=POOR 10=GREAT)
FIREPLACE	FAST	YES	HIGH	ROOM HEATING	LOW	EXTREMELY LOW	MODERATE	1
WOOD STOVE	FAST	YES	LOW	ROOM HEATING OR SMALL HOUSES	LOW	MEDIUM TO HIGH	MODERATE	7
PELLET STOVE	FAST	YES	LOW	ROOM HEATING OR SMALL HOUSES	LOW	MEDIUM TO HIGH	MODERATE	7
MASONRY HEATER	SLOW	YES	LOW	ROOM HEATING OR SMALL HOUSES	HIGH	HIGH	HIGH	9
FORCED AIR (gas or oil)	FAST	NO	GAS - LOW OIL-MEDIUM	WHOLE HOUSE	MEDIUM to high	MEDIUM TO HIGH	MODERATE	5
RADIANT FLOOR (gas)	SLOW	NO unless supplied by heat pump or solar hot water	LOW	WHOLE HOUSE but capable of zone heating	HIGH	MEDIUM TO HIGH	HIGH	9
BASEBOARD HOT WATER	MEDIUM	NO unless supplied by heat pump or solar hot water	LOW	WHOLE HOUSE but capable of zone heating	HIGH	MEDIUM TO HIGH	HIGH	8
HEAT PUMP	FAST	PARTIALLY heat is, but electricity to run them is generally not	LOW	WHOLE HOUSE but capable of zone heating	HIGH	HIGH	HIGH	9
SOLAR HOT WATER	MEDIUM	YES expect for electricity to run pumps	LOW	WHOLE HOUSE but capable of zone heating	HIGH	HIGH	HIGH	9
ELECTRIC BASEBOARD	FAST	NO	HIGH	WHOLE HOUSE and room heating	MEDIUM can produce dry indoor air	LOW	HIGH operating cost	1
WALL HEATER (gas)	FAST	NO	MEDIUM	ROOM HEATING	MEDIUM tends medium to produce hot zones	MEDIUM	LOW	7
WALL HEATER (electric)	FAST	NO	HIGH	ROOM HEATING	MEDIUM	LOW	LOW	1

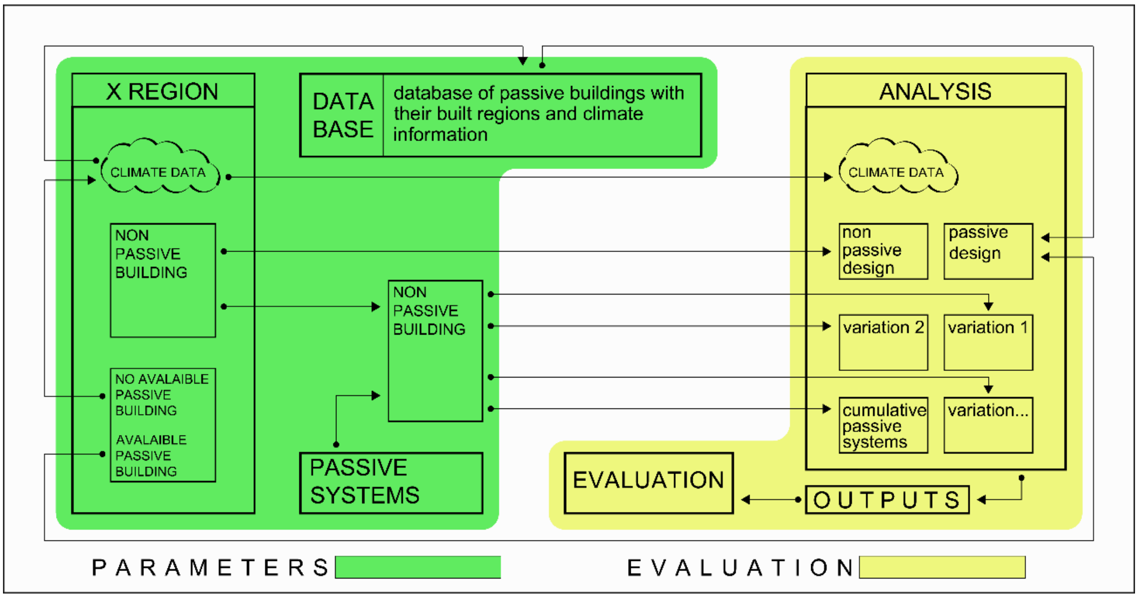
Source: Danien D. Chiras, (2002) The solar house: passive heating and cooling, Chelsea Green Publishing, p.131

4. EVALUATION AND CORRALATION OF THE CASE STUDIES

Research reveals that, buildings designed with passive concept gains energy while consuming low energy. Four building projects are selected to calculate the energy performance. Passive solar principles are incorporated into the projects and each case is evaluated. Ecotect software is used to reveal energy gains in buildings that are designed with passive solar energy approach.

The analysis is completed in two stages as seen in the figure 4.1. Defining parameters of buildings and environmental data is the first stage. Analyzing data via ecotect software and evaluating the outputs are the secondary stage of the research. In the first stage, the buildings and various application of passive measures are defined. Two climatic regions are selected from Turkey. A non-passive and a passive building are selected for each city. Passive principles are applied to the non-passive building projects one at a time to test different conditions. All conditions are gathered in a final case to reveal cumulative effect of different cases. In the second part of the first stage, the physical environmental conditions are defined. Those conditions are taken based on climate information of the selected regions.

Figure 4.1: Research process scheme layout



In a condition of being unavailable to define the passive project pair for a region, alternative projects are sought which are built in a similar climate conditions with the defined region. Found projects are adapted in place of missing passive building.

In the second stage, different conditions of plan layouts are analyzed via ecotect against the defined climatic data. Then correlation and evaluation, of the outputs that gained in the analysis, are carried on in the final stage. In this study analysis are conducted for two different regions. Thereby the process is performed twice. In this study all the parameters taken from regions and buildings are presented primarily then evaluations are carried on.

There are seven groups according to the average winter temperatures in Turkey. The most concentrated group is the fourth, as presented in table 4.1 (MGM, 2014). Primarily, Nevşehir is selected from group 4, as the average winter temperature of the city is close to group's average temperature with 0.7 °C. Then to test passive principles in a more severe winter conditions, a colder region. Thus, the city of Van is selected from mid-section of group 3 with -2.4 °C average winter temperature. Colder regions are selected, because heat gains is crucial in cold climates, it is possible to gain even more energy in warmer regions according to the solar radiation map of Turkey (Yenilenebilir enerji genel müdürlüğü, 2012).

Table 4.1: City groups of average winter temperatures in Turkey

TEMPERATURE FRACTIONS	-10,0 -9,1	-9,0 -8,1	-8,0 -7,1	-7,0 -6,1	-6,0 -5,1	-5,0 -4,1	-4,0 -3,1	-3,0 -2,1	-2,0 -1,1	-1,0 -0,1	0,0 0,9	1,0 1,9	2,0 2,9	3,0 3,9	4,0 4,9	5,0 5,9	6,0 6,9	7,0 7,9	8,0 8,9	9,0 9,9	10,0 10,9
NUMBER OF CITIES 1° C ZONE	1	2	1	0	1	1	1	1	5	4	7	10	2	10	6	4	7	9	2	4	3
NUMBER OF CITIES 3° C ZONE	4			2			7			21			18			20			9		
GROUP	GROUP 1			GROUP 2			GROUP 3			GROUP 4			GROUP 5			GROUP 6			GROUP 7		

Source: Meteoroloji genel müdürlüğü, (2014) İllerimize ait istatistiki veriler, 8. february.2014

4.1 BUILDING PARAMETERS OF CASE STUDY IN NEVŞEHİR

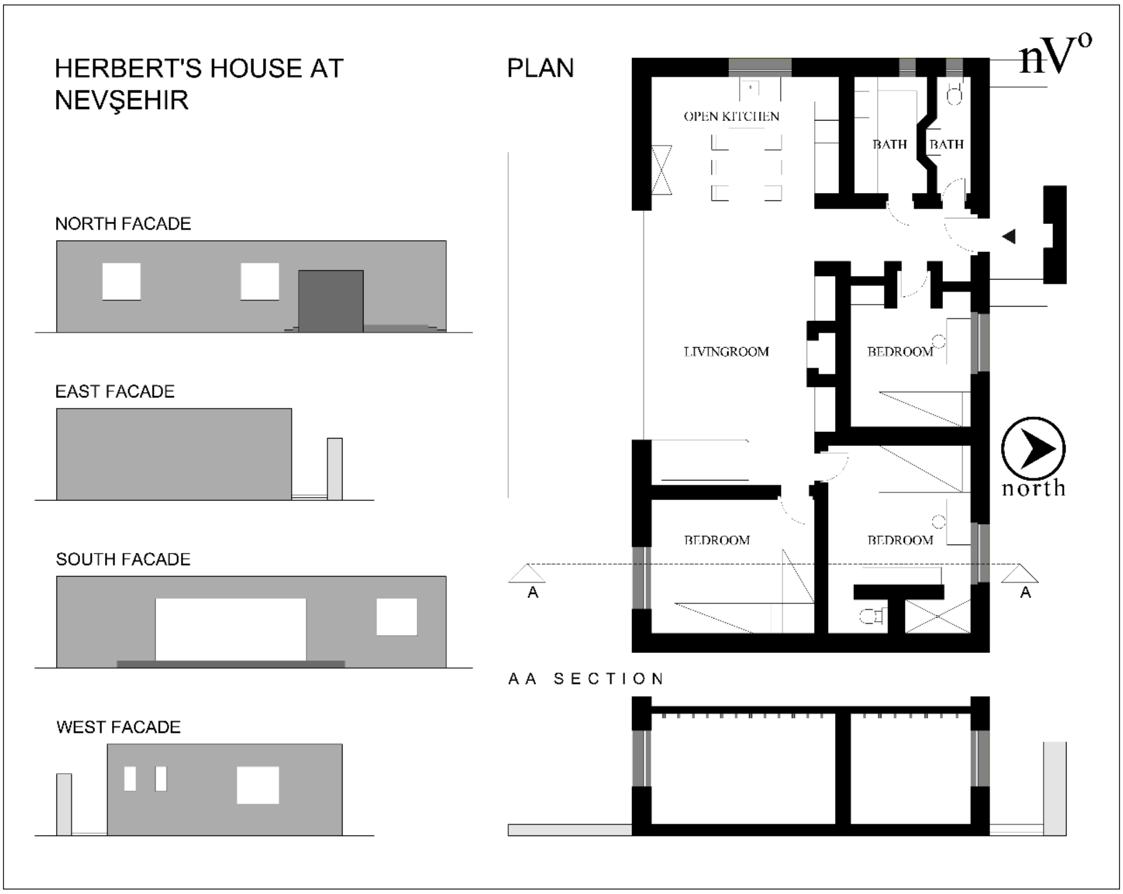
A building in the city of Nevşehir at the Ortahisar district is selected, which is not designed according to the passive concept. After the analysis of the building, three structural principals are considered appropriate for the project in order to gain solar radiation. These modifications are incorporation of exterior thermal walls, heat storage and clerestories, also a secondary insulation layer is applied. Five cases (nV^1, nV^2, nV^3, nV°, nP) are defined according to these modifications. Cases are presented in table 4.2 in detail. A passive building is selected from Putnam Valley United States (U.S.) for analysis, as a result of lack of passive buildings in Nevşehir. Putnam Valley is city in New York with relatively similar climate conditions. Climate of both cities are studied in section 4.2.1 environmental conditions of Nevşehir.

Table 4.2: Detail of groups derived from buildings

GROUP	DETAILED GROUP NAME	MODIFICATION	ORIGIN
nV°	NEVŞEHİR ORIGINAL PLAN LAYOUT	NON	NEVŞEHİR, TR
nV^1	NEVŞEHİR VARIATION 1	INDIRECT GAIN	NEVŞEHİR, TR
nV^2	NEVŞEHİR VARIATION 2	DIRECT GAIN	NEVŞEHİR, TR
nV^3	NEVŞEHİR VARIATION 3	CLERESTORIES	NEVŞEHİR, TR
nV^P	NEVŞEHİR CUMULATIVE CONDITION	CUMULATIVE	NEVŞEHİR, TR
nP	NEVŞEHİR PASSIVE BUILDING LAYOUT	NON	PUTNAM VALLEY, U.S.

Original plan layout (nV°) of the building in Nevşehir has three bedrooms, two bathroom and one living room as seen in the figure 4.2. The total area (without wall areas) is 113 square meter. The building's structure is reinforced concrete and the earth masonry is used for wall construction (Argos, 2009). The total window area is 25.8 square meter and 17.7 square meter of this amount is south facing window.

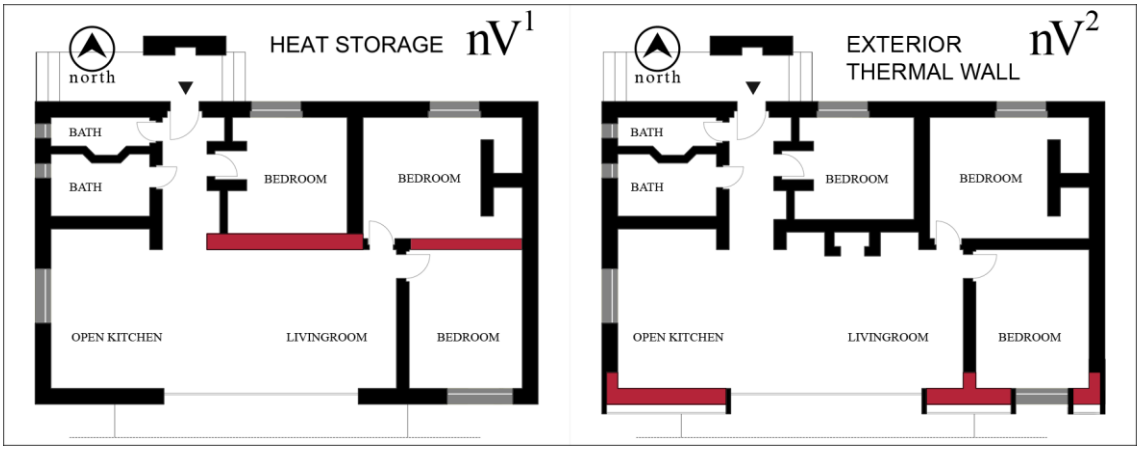
Figure 4.2: Original plan layout of building in Nevşehir



Source: Argos Yapı, (2007) http://www.argosyapi.com/?Dep=Projeler&ProjeNo=8, (10.april.2014)

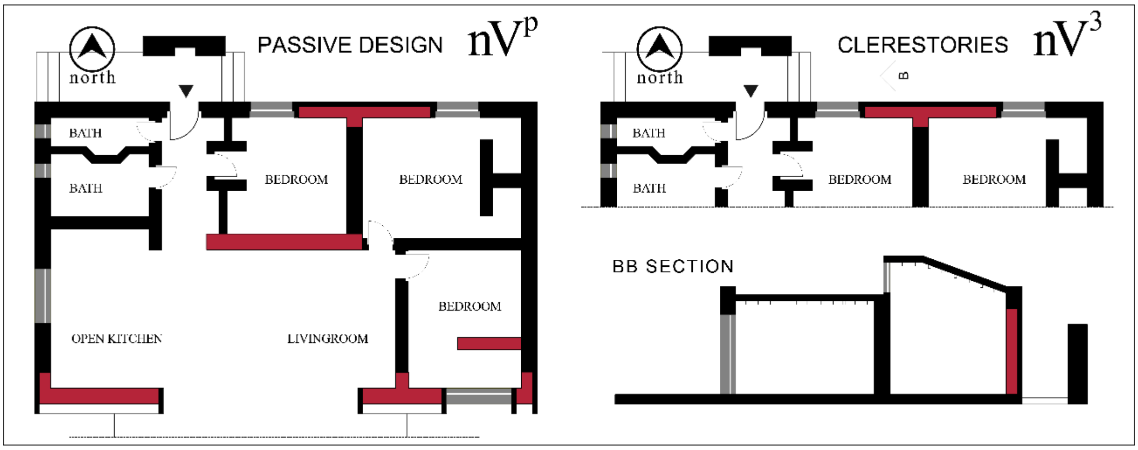
In the first case (nV^1) exterior thermal wall system is completely adapted to south facade. The entire south facade is digitally constructed with adobe bricks to convert exterior wall into a thermal storage in 3d model as marked in figure 4.3. Exterior surface of the wall painted black and covered glazing with leaving 5 cm of air gab between wall and glazing. Applied thermal mass amount is 15 m^3 in case nV^1. In the second case (nV^2) adobe heat storage walls were added to living room and master bedroom as seen in the figure 4.2. A 7.23 m^3 wall placed to living room. Another 4.86 m^3 wall has been added to master.

Figure 4.3: Heat storage and exterior thermal wall systems



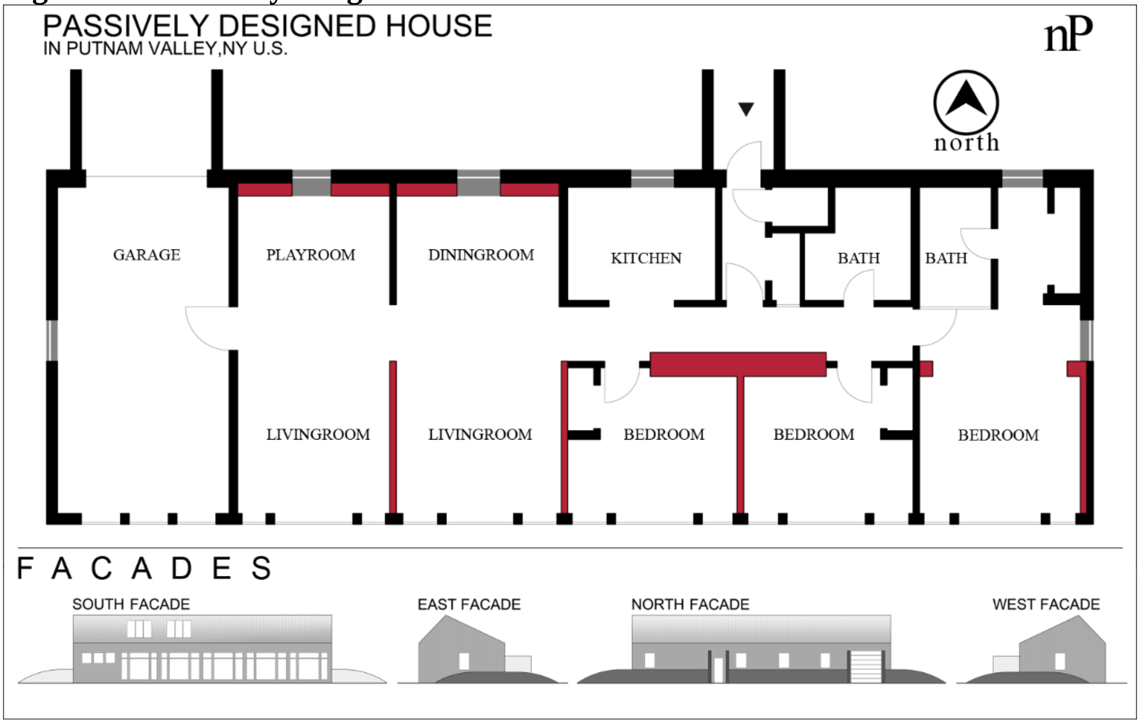
In third proposal, clerestories are added for increasing the passive performance as seen in the figure 4.4 (nV^3). In this system roof of the building and north exterior wall are modified. 4.8 m^3 of adobe wall added to north exterior wall. To protect heat storage, adobe wall's exterior surface covered with a secondary wall layer. In the final stage, all modifications concerning passive systems are gathered to calculate the overall performance of the building as seen in the figure 4.4 (nV^P).

Figure 4.4: Clerestories and complete set of passive systems



The house in Putnam Valley, NY was designed according to the passive solar concept as seen in figure 4.4 (nP). The building is protected with 1.2 m of the earth berm from east west and north sides. The north facade has a second layer of insulation for extra protectionin. The entire south facade is covered with solar gain windows and they are sealed with automated (sliding from roof to bottom of the floor) garage doors instead of classic shutters for protection from cold at night. Also to store gained heat, masonry thermal walls are built inside the building as marked red in figure 4.5 and whole floor designed as a thermal storage with ceramic floor tiles. To block the cold striking from north bathrooms, dressing rooms and kitchen at placed at north side in plan layout. The building has 140 square meter of interior space. Clerestories are opened in roof to gain extra heat for common spaces like dining, living and play rooms with thermal walls placed at north side of the room as marked in figure 4.5 (HUD, 1982, pp. 34-37). Features of all selected buildings and cases are presented in table 4.3.

Figure 4.5: Passively designed house



Source: United States. Department of Housing and Urban Development, (1982) Passive solar homes: 91 new award-winning, energy-conserving single-family homes with specific suggestions for design & construction, Dodd, Mead & Co. p.34-37

Table 4.3: Summary of the modifications

	nP	nV^o	nV^1	nV^2	nV^3	nV^P
Direct Thermal Mass Amount	34,5 m^3	-	15 m^3	-	5,5 m^3	20,5 m^3
Indirect Thermal Mass Amount	-	-	-	14,3 m^3	-	14,3 m^3
Passive Gain Elements	Direct Gain	-	Indirect Gain	Direct Gain	Clerestories	Cumulative
South Window Area	49 m^2	17,7 m^2	17,7 m^2	17,7 m^2	26,2 m^2	26,2 m^2
Total Window Area	57,5 m^2	25,8 m^2	25,8 m^2	25,8 m^2	34,3 m^2	34,3 m^2
South Facade Area	89,2 m^2	58,3 m^2	58,3 m^2	58,3 m^2	58,3 m^2	70 m^2
East + West Facade Area	69,5 m^2	70,3 m^2	70,3 m^2	70,3 m^2	77 m^2	77 m^2
Building Area	140 m^2	130 m^2	130 m^2	130 m^2	130 m^2	130 m^2
North Facade Area	59,4 m^2	58,3 m^2	58,3 m^2	58,3 m^2	58,3 m^2	58,3 m^2
Exterior & Interior Wall Material	Earth Masonry	Earth Masonry	Earth Masonry	Earth Masonry	Earth Masonry	Earth Masonry
Thermal Mass Material	Adobe Brick	-	Adobe Brick	Adobe Brick	Adobe Brick	Adobe Brick

4.1.1 Environmental Conditions of Nevşehir

The proximity between average climate profile of Turkey and Nevşehir is very close (MGM, 2014). The climate in Nevşehir is mesodermal (Klimatoloji Şube Müdürlüğü, 2014, p. 15). Thus Nevşehir has hot summers with medium dry air and cold winters with rain as seen in the table 4.4. Also the humidity level of the city is B1 (Thornthwaite climate classification), because of its summer air.

Putnam Valley is the construction area of the compared passive house. This city takes place in New York, United States. As seen in the table 4.4 the climate of the Putnam Valley is close to Nevşehir. But Putnam receives slightly more rain from Nevşehir, thus its humidity level is B3 (NOAA, 2014).

Table 4.4: Weather data of Nevşehir and Putnam Valley

NEVSEHIR — WEATHER DATA (1)	January	February	March	April	May	June	July	August	September	October	November	December
Average temperature (°C)	-0,4	0,6	4,7	9,9	14,5	18,5	21,7	21,3	17	11,8	6,2	1,9
Average highest temperature (°C)	3,7	5,1	9,9	15,6	20,3	24,6	28,3	28,3	24,3	18,2	11,4	6
Average lowest temperature (°C)	-3,9	-3,1	0,3	4,9	8,5	11,3	13,2	13	9,9	6,5	2,2	-1,5
Monthly average rain amount (kg/m^2)	42,2	42,4	45,6	52	59,2	32,5	8,7	4,6	11,9	30,9	36	50,4
Highest recorded temperature (°C)	18,6	18,8	28	31,6	32,6	34,2	39,5	38,2	35,2	32	24,6	23
Lowest recorded temperature (°C)	-21,2	-23,6	-18	-12,5	-2,3	1,3	3,8	3,1	-1,2	-7,6	-14	-19,5

PUTNAM VALEY, Ny — WEATHER DATA (2)	January	February	March	April	May	June	July	August	September	October	November	December
Average temperature (°C)	-2	-1	4	11	16	21	24	23	18	12	7	1
Average highest temperature (°C)	2	4	9	16	22	27	29	28	24	17	11	4
Average lowest temperature (°C)	-7	-5	-2	4	10	15	18	17	13	7	2	-3
Monthly average rain amount (mm)	93	81	98	104	104	115	116	117	113	126	110	106
Highest recorded temperature (°C)	22	22	29	36	36	39	39	39	41	32	28	22
Lowest recorded temperature (°C)	-26	-24	-18	-9	-3	4	7	5	0	-6	-12	-22

Source: 1 Meteoroloji işleri müdürlüğü, http://www.dmi.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=nevsehir, 22.march.2014

2 National Weather Service,http://forecast.weather.gov/afm/PointClick.php?lat=41.34000&lon= -73.87000, 22.march.2014

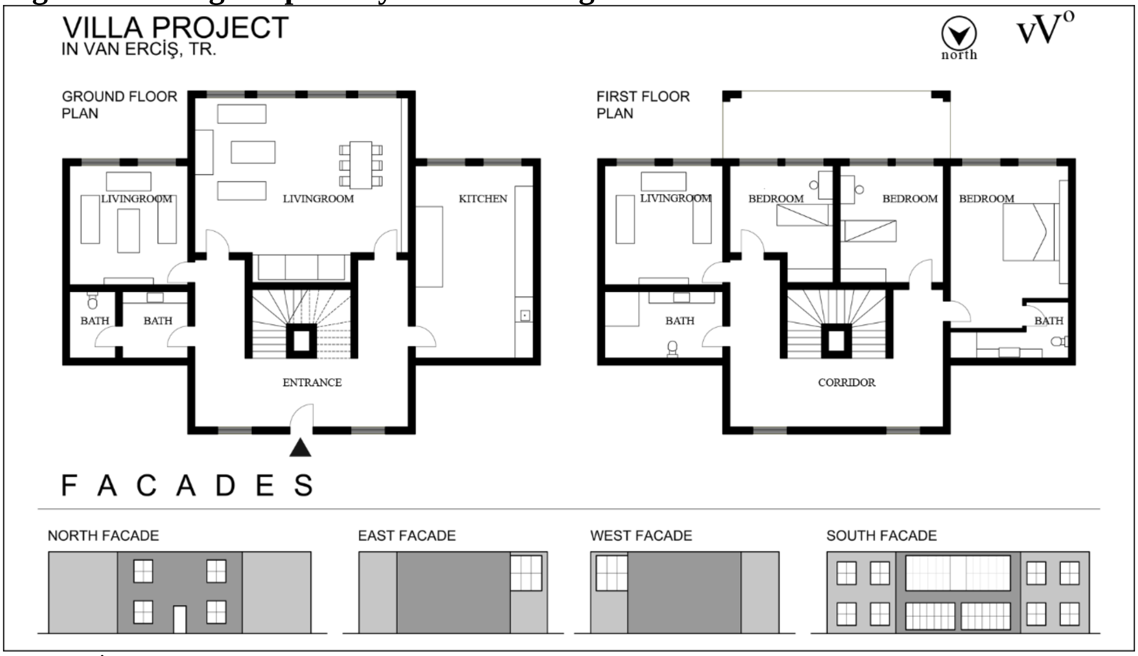
4.2 BUILDING PARAMETERS OF CASE STUDY IN VAN

The non-passive building for Van is selected from Erciş district. The passive principles of direct gain and greenhouse is planned for modifications after review of building, also thermal storage walls and secondary layer of insulation is applied for all proposals. Two case groups (vV^1, vV^2) are created for proposals and two groups (vV°, vP) are created for original plan layout and passively designed building as seen in table 4.5. The passive building for Van is selected from Durham in New Hampshire U.S. Climate conditions of both regions are studied in section 4.2.1 environmental conditions of Van. Original plan layout has (vV°) several rooms and a balcony in 492 m^2 area as seen in the figure 4.6. The south facade covers 135.2 m^2 area and 42 m^2 of this amount is south window (İL-SA, 2012).

Table 4.5: Detail of groups derived from buildings

GROUP	DETAILED GROUP NAME	MODIFICATION	ORIGIN
vV°	VAN ORIGINAL PLAN LAYOUT	NON	VAN, TR
vV^1	VAN VARIATION 1	DIRECT GAIN	VAN, TR
vV^2	VAN VARIATION 2	GREENHOUSE	VAN, TR
vV^P	VAN CUMULATIVE CONDITION	CUMULATIVE	VAN, TR
vP	VAN PASSIVE BUILDING LAYOUT	NON	DURHAM, U.S.

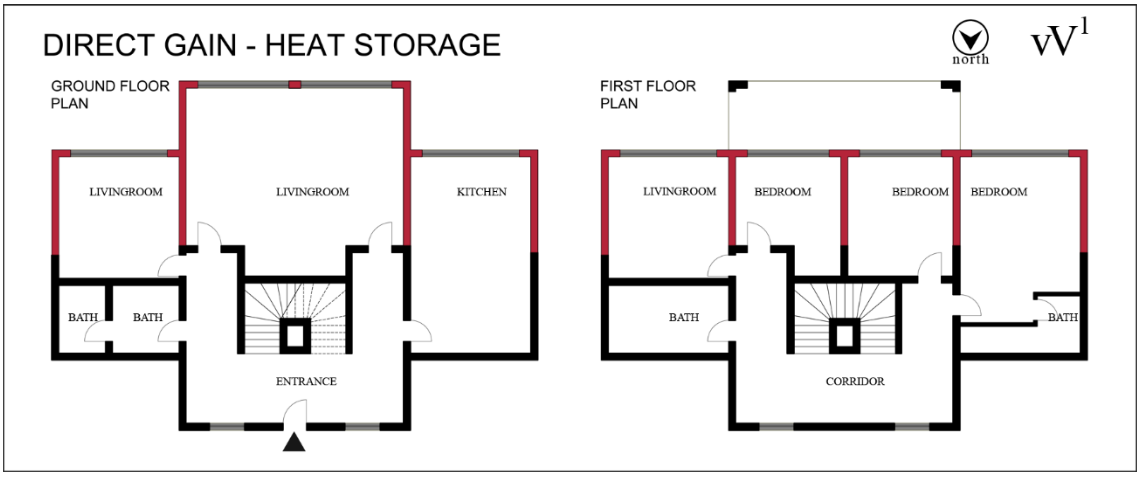
Figure 4.6: Original plan layout of building in Van



Source: İL-SA, (2012) http://naturalifeilsa.com, (16.april.2014)

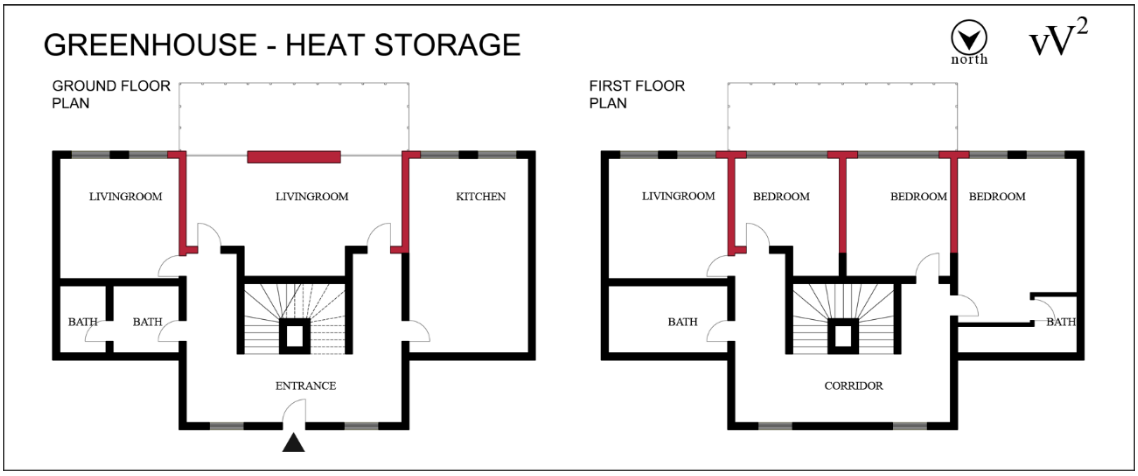
In the first proposal (vV¹) south windows of both floors are enlarged to increase solar gain, also south walls and floors are changed to adobe for heat storage, as seen in the figure 4.7. After modifications south window area increased to 71.9 m^2 in 3d model, also 41.5 m^3 thermal storage is added to design.

Figure 4.7: First proposal plan layout



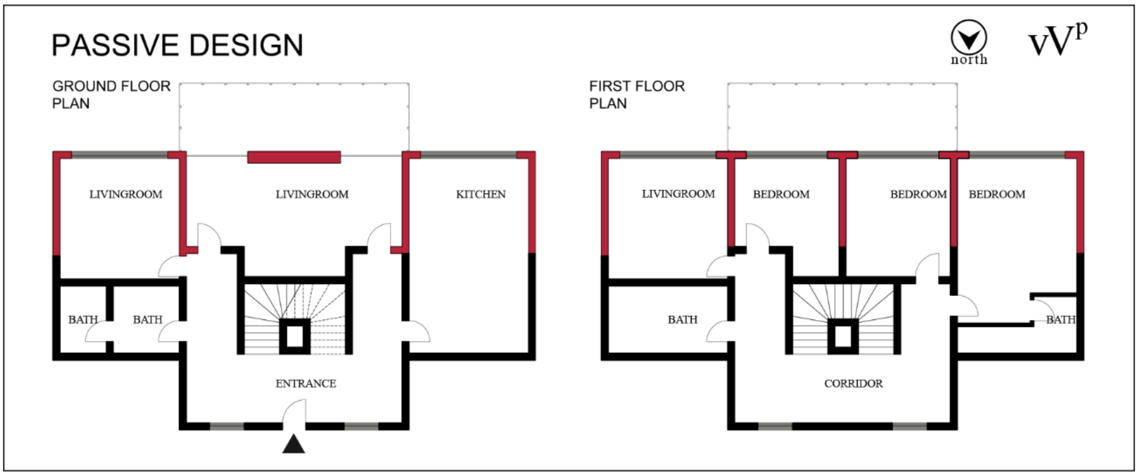
In the second (vV²) proposal, balcony is combined with ground floor to form a greenhouse as seen in the figure 4.8. Windows and walls between greenhouse and building, changed to glazing panels in 3d model. Thermal storage is added to bedrooms and living room. Total exterior south windows are increased to 59.8 m². Amount of added thermal storage is 26.5 m³ in second proposal.

Figure 4.8: Second proposal plan layout



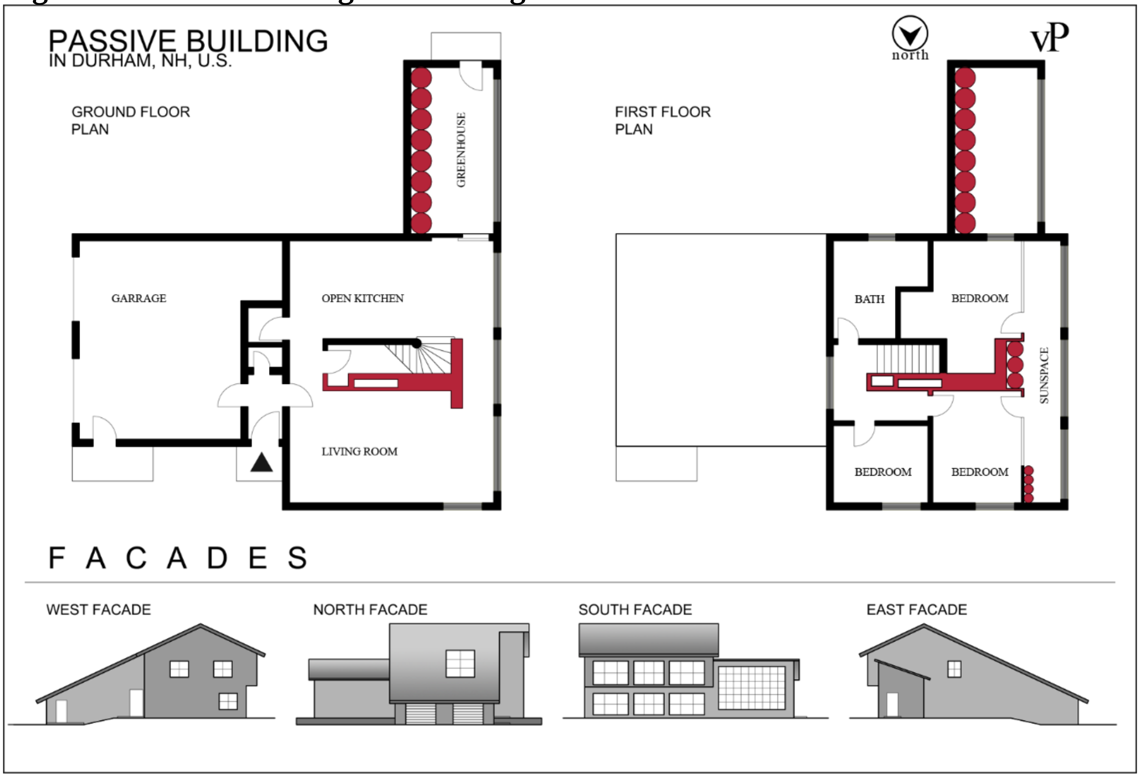
In the final cumulative proposal (vVᴾ) both direct gain and greenhouse principles are used as seen in the figure 4.9. South glazing area was increased to 87.5 m², also for the final case thermal storage amount is 43 m³.

Figure 4.9: Final cumulative proposal



The building (vP) in Durham designed completely according to the passive solar energy concept (HUD, 1982, p. 48). The saltbox roof acts like shield against north winds as seen in the figure 4.10. Garage is placed on the north side of the building to block cold. The main entrance doorway is protected with secondary doors to isolate interior. East west and north windows are limited with total area of 269 m², but glazing area is extensive on south facade with 64 m². Except the south facade, solar gain is also provided via attached greenhouse. 25 m³ water is used as thermal storage material in tanks for both the building and the greenhouse. In addition to water tanks, concrete slaps which are finished with natural stone on the south and stone mass wall which is an extension of woodstove in ground floor, are designed as thermal storage. Due to the open planning, gained heat is easily distributed to interior space of the building (HUD, 1982, p. 49). Blankets are pulled down to all windows at night for protection from heat loss during the night. Features of all selected buildings for Van and proposals are presented in groups as seen in table 4.6.

Figure 4.10: Passive designed building



Source: United States. Department of Housing and Urban Development, (1982) Passive solar homes: 91 new award-winning, energy-conserving single-family homes with specific suggestions for design & construction, Dodd, Mead & Co. p.48-49

Table 4.6: Summary of the modifications

	vP	vV^o	vV^1	vV^2	vV^P
Direct Thermal Mass Amount	35 m^3	-	41,58 m^3	26,5	43 m^3
Indirect Thermal Mass Amount	-	-	-	-	-
Passive Gain Elements	Direct Gain	-	Indirect Gain	Direct Gain	Cumulative
South Window Area	64 m^2	42 m^2	71,96 m^2	59,8 m^2	87,5 m^2
Total Window Area	74,5 m^2	52,8 m^2	81,96 m^2	69,8 m^2	97,5 m^2
South Facade Area	108 m^2	135,2 m^2	135,2 m^2	135,2 m^2	135,2 m^2
East + West Facade Area	148 m^2	194,4 m^2	194,4 m^2	194,4 m^2	194,4 m^2
Building Area	269,3 m^2	246 m^2	246 m^2	216,8 m^2	216,8 m^2
North Facade Area	38 m^2	135,2 m^2	135,2 m^2	135,2 m^2	135,2 m^2
Exterior & Interior Wall Material	Earth Masonry	Earth Masonry	Earth Masonry	Earth Masonry	Earth Masonry
Thermal Mass Material	Adobe Brick & Water	-	Adobe Brick	Adobe Brick	Adobe Brick

4.2.1 Environmental Conditions of Van

The city of Van is a cold region according to the average temperatures in Turkey (MGM, 2014). Most of the rain occurs in winter, so Van has a semi-dry climate with c1 humidity level (Thornthwaite climate classification) (Klimatoloji Şube Müdürlüğü, 2014, p. 15). The annual temperature profiles of Van and Durham are presented in table 4.7. The winter temperature and humidity averages are -2.4 °C to 56 percent in Van and -2.6 °C to 70 percent in Durham (MGM, 2014) (NOAA, 2014).

Table 4.7: Weather data of Van and Durham

VAN — WEATHER DATA [1]	January	February	March	April	May	June	July	August	September	October	November	December
Average temperature (°C)	-3,5	-2,9	1,5	7,7	13,1	18,2	22,3	21,9	17,2	10,7	4,3	-0,7
Average highest temperature (°C)	1,8	2,5	6,5	12,6	18,2	23,6	27,9	28	23,9	17,2	10,1	4,5
Average lowest temperature (°C)	-7,7	-7,2	-2,7	2,9	7,1	11	14,8	14,8	10,9	5,8	0,3	-4,4
Monthly average rain amount (kg/m^2)	31,8	33	45,6	57,2	46,6	18,8	5,1	3,4	13,9	45,5	47,7	37,3
Highest recorded temperature (°C)	12,6	13,6	22,7	27,2	28,3	33,2	37,5	35,1	35	27	20,1	15,5
Lowest recorded temperature (°C)	-28,7	-28,2	-22,7	-17,5	-1,5	-2,6	6,5	6,6	-0,1	-7,5	-18,6	-21,3

DURHAM, NH — WEATHER DATA [2]	January	February	March	April	May	June	July	August	September	October	November	December
Average temperature (°C)	-4	-2	2	8	14	19	22	21	17	10	5	-2
Average highest temperature (°C)	1	3	8	15	21	26	28	27	23	17	10	3
Average lowest temperature (°C)	-10	-8	-4	1	7	12	15	14	10	3	-1	-7
Monthly average rain amount (mm)	71.1	79.5	105.2	107.9	101.3	99.6	107.4	89.9	96.5	110.7	115.3	87.4
Highest recorded temperature (°C)	20	22	32	35	35	37	39	39	37	33	27	23
Lowest recorded temperature (°C)	-37	-34	-28	-13	-6	-1	2	-2	-6	-15	-25	-35

Source: 1 Meteoroloji işleri müdürlüğü, http://www.dmi.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=nevsehir, 22.march.2014
2 National Weather Service,http://forecast.weather.gov/MapClick.php?lat=43.133969322000496&lon=-70.92644628099964&site=all&smap=1

4.3 SOFTWARE OUTPUTS

In this part a brief information is given in order to adapt the survey made by the software to the study. In this study, the effects of passive principles which are made to 3d models of selected non passive projects are surveyed via Ecotect software. The data output of the software is defined and explained. The raw data outputs of Ecotect software are presented in appendices 1.

In order to receive realistic and precise results precautions are taken. In the analysis evaluation and correlation energy is defined by watt-hour (Wh). For all of the proposals under a case study, the layers of exterior and interior walls are equal in thickness and order, also all the windows in the buildings are defined as double glazing.

In data outputs of the software the solar gains are inspected under heat flow paths of direct gain, indirect gain and inter-zonal gains. Even though ecotect defined those gains in different flow path as seen in the table 4.8, the software's definitions do not overlap with architectural definitions. As seen in the definitions of table 4.8 indirect gains only could gained by exterior walls, also the solar radiation that strikes to glazing is always calculated as direct gain. On the contrary, glazing could be a component of indirect gain as studied in chapter 3 exterior thermal walls and roof ponds sections.

Table 4.8: Ecotect definitions for gain flows

Direct Solar Gains	Heat flow through windows and other transparent external surfaces due to the transmission of incident solar radiation directly into each space.
Indirect Solar Gains	The extra heat flow through opaque external surfaces due to increased differential surface temperatures resulting from incident solar radiation.
Inter-Zonal Gains	Heat flow deu to temperature differences between adjacent zones. This occurs through internal walls, floors and ceilings. This includes ground effects as the ground is basically a virtue zone

Source: Autodesk Ecotect (2011), Calculation wizard

Heat gains by electric lights, appliances, other equipment and actual occupants of the buildings are neglected. The sun is considered as the only heat source in the analysis. The analysis are made based on complete solar exposure without any obstacle to cast shadow on case studies during the sun time.

4.4 ENERGY PERFORMANCE ANALYSIS OF CASE STUDIES

The results of the analysis reveal the amount of energy gained from the sun during entire year. But this study focuses and evaluates only on the heat gains during winter season, also the first months (November and March) of beginning and ending of winter season are included to evaluation. The residential buildings annually consume approximately between 5000 kWh to 33000 kWh according to their built zone and structural features (Energy efficiency deployment office, 2012, p. 4).

4.4.1 Evaluation and Correlation of Case Studies in Nevşehir

Selected buildings and cases are analyzed with given parameters. Received analysis data reveals the increase in heat gains with the passive systems as seen in the table 4.9. Also according to data, the amount of solar gain is in proportion with thermal mass. Additionally data reveals building, which designed with passive solar approach from the start, is more efficient at gaining energy.

Table 4.9: Passive gains in Nevşehir region

ENERGY GAINS (kWh) variation	nP					nV^{o}					nV^{1}				
months	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR
Direct Solar Gains	33,9	27,6	34,7	43,2	53,4	3,9	3,7	4,1	4,6	4,6	8,7	7,8	8,5	10,7	12,4
Indirect Solar Gains	16,2	14,6	16,6	20,7	23,6	1,9	1,6	1,9	2,3	2,8	20,3	17,3	20,4	25,7	31,1
Inter-zonal Gains	18,7	25,3	27,3	25,8	18,0	3,3	9,1	10,7	9,1	3,1	3,8	9,7	11,3	9,7	3,6
Monthly Total Gains	68,8	67,5	78,7	89,6	94,9	9,1	14,4	16,7	16,0	10,4	32,8	34,7	40,3	46,1	47,1
Total Gains	399,6					66,8					201,1				

ENERGY GAINS (kWh) variation	nV^{2}					nV^{3}					nV^{P}				
months	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR
Direct Solar Gains	4,9	4,6	5,2	5,7	5,7	12,0	11,3	12,9	13,8	13,1	18,1	16,6	18,5	21,6	23,0
Indirect Solar Gains	17,7	16,0	17,9	21,0	23,5	2,3	2,0	2,3	2,9	3,5	23,9	19,4	23,2	31,3	41,1
Inter-zonal Gains	3,6	9,4	10,9	9,3	3,2	3,5	9,3	10,9	9,3	3,3	9,9	15,6	17,1	15,4	9,0
Monthly Total Gains	26,2	30,0	34,0	36,0	32,4	17,9	22,7	26,1	26,0	19,9	51,9	51,6	58,8	68,3	73,1
Total Gains	158,6					112,6					303,8				

In case nV° heat gain occurs at minimum. Even though the building wall material is stone, as a result of design approach the building cannot absorb solar radiation efficiently. Stone is thermal storage material but the applied plaster and paint, isolates stone from solar radiation. In the nV^{1} and nV^{2} cases the heat storage amount is almost equal, but the distance from glazing effects the direct gain in nV^{2}. So gain per m^3 is higher in case nV^{1} as seen in the table 4.10.

Table 4.10: Unit gains

ENERGY GAINS variation	nP	nV^o	nV^1	nV^2	nV^3	nV^P
Total Solar Gains (kWh)	399,6	66,8	201,1	158,6	112,6	303,8
Thermal Mass Amount (m^3)	34,5	-	15,0	14,3	5,5	34,8
Total Solar Gains / m^2	2,9	0,5	1,5	1,2	0,9	2,3
Total Gains / Thermal Mass (kWh/m^3)	11,6	-	13,4	11,1	20,5	8,7

The case nV^3 has the most modifications, yet data reveals the heat gain is at minimum among the cases. The original design of the building limit the adding clerestories and also this addition increases the east and west facade surfaces. The nV^P has higher heat gain than other cases, but the gain in nP is the highest. The difference in plan layouts of nV^P and nP is the form. The nV^P is close to square shape but the nP has an east-west elongated shape and this factor cannot be modified with post construction.

The minimum heat gain is 69 percent as seen in table 4.11. Expensive modifications could increase solar gain with 355 percent. But the gains with modifications cannot reach passively designed building (nP).

Table 4.11: Gain percentages in detail

ENERGY GAINS (kWh) variation	nP					nV^o					nV^1				
months	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR
Direct Solar Gains	30,0	23,9	30,6	38,6	48,8	0,0	0,0	0,0	0,0	0,0	4,7	4,1	4,4	6,1	7,8
Indirect Solar Gains	14,4	13,0	14,8	18,4	20,8	0,0	0,0	0,0	0,0	0,0	18,4	15,6	18,5	23,4	28,4
Inter-zonal Gains	15,3	16,2	16,6	16,6	14,9	0,0	0,0	0,0	0,0	0,0	0,5	0,6	0,6	0,6	0,5
Monthly Total Gains	59,7	53,1	61,9	73,6	84,5	0,0	0,0	0,0	0,0	0,0	23,7	20,3	23,5	30,1	36,7
Total Gains			332,8	% 499				0,0	% 0,0				134,3	% 201	

ENERGY GAINS (kWh) variation	nV^2					nV^3					nV^P				
months	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR
Direct Solar Gains	1,0	0,9	1,1	1,2	1,1	8,1	7,7	8,8	9,2	8,5	14,1	12,9	14,4	17,0	18,4
Indirect Solar Gains	15,8	14,4	16,0	18,7	20,8	0,5	0,4	0,4	0,6	0,8	22,1	17,8	21,4	29,0	38,3
Inter-zonal Gains	0,2	0,2	0,2	0,1	0,1	0,2	0,2	0,2	0,2	0,2	6,5	6,5	6,4	6,3	6,0
Monthly Total Gains	17,1	15,6	17,2	20,0	22,0	8,7	8,2	9,4	10,0	9,5	42,7	37,2	42,1	52,3	62,7
Total Gains			91,9	% 138				45,8	% 69				237,0	% 355	

4.4.2 Evaluation and Correlation of Case Studies in Van

The effects of modifications which are made in first (vV^1) and second (vV^2) proposals provide additional solar gain in relation to the original plan layout as presented in the table 4.12. The amount of glazing area and thermal storage in the vV^2 is lower than vV^1. The difference between proposals decreases the solar gain with 52.51 kWh. In addition to this, the solar gain is calculated maximum in the cumulative proposal (vV^P). In this case study, the most solar gain occurs in the passively designed building (vP), but the maximum thermal mass is placed in proposal vV^P. The difference between the two plan layouts is the orientation of the heat storage walls. In vP thermal mass faces directly to south, but in vV^P walls are vertical to south due to the original design approach. The thermal walls which are not exposed to direct solar radiation, do not operate efficiently, also the north facade that is equal to south facade limits the solar gain by exposing the building to northern winds. This reveals the direct effect of simple decisions on the heat gain, which are taken in the design process.

Table 4.12: Passive gains in Nevşehir region

ENERGY GAINS (kWh) variation	vP					vV^o					vV^1				
months	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR
Direct Solar Gains	102,2	85,3	100,6	131,2	163,7	70,5	67,0	75,4	81,5	80,7	87,9	83,5	94,3	101,1	99,0
Indirect Solar Gains	68,7	61,5	71,2	84,8	94,3	5,0	4,3	5,0	6,4	7,7	22,5	18,2	22,4	29,7	38,8
Inter-zonal Gains	4,8	13,1	15,2	12,8	4,1	5,0	13,8	16,2	13,8	4,7	5,5	14,3	16,7	14,2	4,9
Monthly Total Gains	175,7	159,9	187,1	228,8	262,1	80,5	85,1	96,7	101,7	93,1	115,8	116,1	133,4	145,0	142,8
Total Gains	1013,6					457,0					653,1				

ENERGY GAINS (kWh) variation	vV^2					vV^P				
months	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR
Direct Solar Gains	57,1	53,6	60,1	67,0	68,2	70,6	63,9	72,7	85,6	94,7
Indirect Solar Gains	40,8	33,5	39,8	53,5	70,0	75,9	62,1	74,7	101,2	133,7
Inter-zonal Gains	5,8	14,5	16,9	14,5	5,3	5,9	14,7	17,1	14,5	5,1
Monthly Total Gains	103,6	101,7	116,8	135,0	143,5	152,5	140,7	164,4	201,3	233,5
Total Gains	600,5					892,4				

The gains per unit m² and m³ are presented in table 4.13. Even the total solar gain is more in vV^1, the unit gain per m³ in vV^2 is higher. This reveals the effectiveness of the greenhouse in vV^2. The unit gain decreases in vV^P, as it a cumulative case of first and second proposals. Despite the low amount of thermal storages in VP, the unit gain is the highest. The wide surfaces of thermal storage walls are directly exposed to south, but in proposals the walls have the gain via convection and this decreases the efficiency of the thermal storages.

Table 4.13: Unit gains

ENERGY GAINS variation	vP	vV^o	vV^1	vV^2	vV^P
Total Solar Gains (kWh)	1013,6	457,0	653,1	600,5	892,4
Thermal Mass Amount (m³)	34,0	-	41,6	26,5	43,0
Total Solar Gains / m²	3,8	0,9	1,3	1,3	1,9
Total Gains / Thermal Mass (kWh/m³)	29,8	-	15,7	22,7	20,8

The differences in solar gain based on the original plan layout (vV°) are presented in table 4.14. The modifications in the vV^{1} increases the total solar gain with 43 percent. The greenhouse and thermal storage in vV^{2} have additional 31 percent of solar gain based on vV°. The highest solar gain is occurred in vP among the group with 122 percent. The solar gain in vV^{P} limited with 95 percent, due to design approach.

Table 4.14: Gain percentages in detail

ENERGY GAINS (kWh) variation	vP					vV°					vV^{1}				
months	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR
Direct Solar Gains	31,7	18,3	25,2	49,6	83,0	0,0	0,0	0,0	0,0	0,0	17,4	16,5	18,9	19,6	18,3
Indirect Solar Gains	63,8	57,2	66,2	78,4	86,5	0,0	0,0	0,0	0,0	0,0	17,5	13,9	17,4	23,4	31,1
Inter-zonal Gains	-0,2	-0,8	-1,0	-1,0	-0,5	0,0	0,0	0,0	0,0	0,0	0,5	0,5	0,5	0,4	0,3
Monthly Total Gains	95,3	74,8	90,4	127,1	169,0	0,0	0,0	0,0	0,0	0,0	35,4	31,0	36,7	43,3	49,7
Total Gains			556,5	% 122				0,0	% 0,0				196,0	% 43	

ENERGY GAINS (kWh) variation	vV^{2}					vV^{P}				
months	NOV	DEC	JAN	FEB	MAR	NOV	DEC	JAN	FEB	MAR
Direct Solar Gains	-13,4	-13,3	-15,4	-14,6	-12,6	0,2	-3,1	-2,7	4,1	13,9
Indirect Solar Gains	35,8	29,2	34,8	47,2	62,3	71,0	57,8	69,7	94,8	126,0
Inter-zonal Gains	0,7	0,7	0,7	0,7	0,7	0,9	0,9	0,8	0,7	0,5
Monthly Total Gains	23,2	16,6	20,1	33,3	50,4	72,0	55,6	67,8	99,5	140,4
Total Gains			143,5	% 31				435,3	% 95	

5. CONCLUSION

This study presents the principles to passively absorb and utilize solar radiation. These principles provide building heat gain and they could be applied to buildings during the design stage or in some cases after construction. But after construction the applications of passive principles are limited due to preserving structural integrity of the building. It is necessary to start at preliminary design stage of the building to apply completely the passive principles without additional costs and limitations.

Applying passive solar design concept on existing projects and on preliminary design stages is shown to be beneficial in terms of energy gain quantitatively. Therefore it reduces the consumption fossil fuels in winter seasons. Nevertheless applications made after the construction and passively designed buildings have different effects on energy gains. The buildings which are constructed with passive design approach, do not necessarily create additional expenses on the budget, further they operate with high performance. However passive solar gain applications after construction cause additional expenses, but the profitability of the gained performance with those modifications is open for discussion. Appling simple rules of passive solar energy on designs surely provides additional heat gains to structure, but the complete adaption of passive solar principles generates high amounts of energy gain. According to the efficiency of the design, passive buildings could maintain the interior heat without much fossil fuel consumption.

This study is revealed the advantages of passive usage of the sun. However research is based upon only one and two floor buildings. Those buildings are mostly located in rural areas and villages. Thus, this study could be used for these regions. Nevertheless rare applications of passive concept limit the gains to the individual levels. To effect the energy production in Turkey, widespread usage of passive solar concept is necessary. For next the phase of the research, the usage of passive solar concept for low rise buildings in cities ought to be researched, as the major building stocks are located in cities.

The natural balance of the earth has vital importance for humans. Fossil fuel production and consumption need to be controlled to protect this balance, also regulations should be constituted for energy requirements. Considering the energy consumption in buildings for heating, and understanding the massive potential of the sun, passive solar energy is an option to use in architecture for today and in the future.

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APPENDICES

APPENDICES 1: Analysis Outputs

ANNUAL LOADS TABLE

MONTHLY AVERAGES (Wh) nVº

Inter-zonal Gains (Wh) nVº

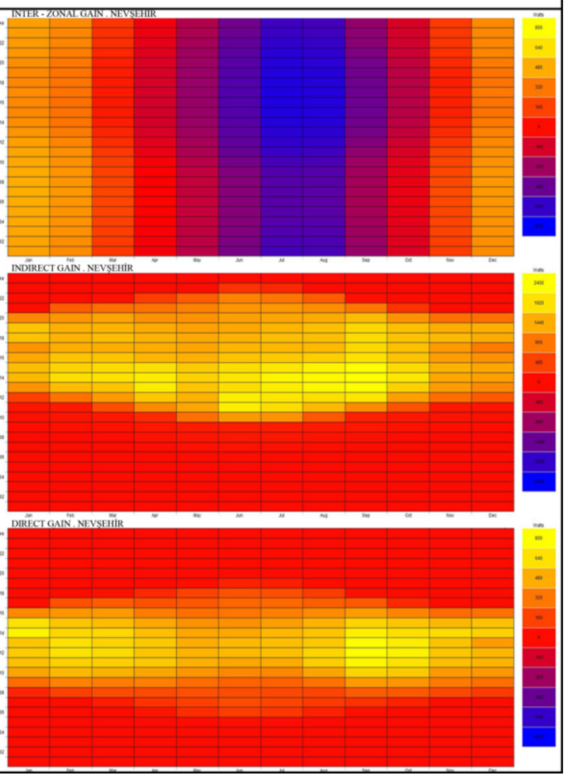
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	455	389	139	-62	-245	-433	-580	-572	-340	-136	148	388
1	457	391	141	-60	-241	-429	-576	-569	-338	-134	150	390
2	459	392	143	-58	-239	-427	-573	-566	-335	-132	152	392
3	460	394	145	-56	-238	-425	-571	-564	-333	-130	153	393
4	461	395	146	-55	-237	-424	-570	-563	-331	-128	155	394
5	462	396	147	-56	-240	-429	-574	-565	-331	-127	156	395
6	463	396	145	-60	-245	-434	-579	-570	-336	-130	156	396
7	460	391	139	-66	-249	-440	-585	-576	-344	-138	149	391
8	452	383	131	-75	-256	-446	-592	-585	-355	-147	141	384
9	444	376	123	-82	-263	-453	-600	-593	-364	-156	134	377
10	438	370	117	-88	-268	-459	-607	-600	-372	-163	127	371
11	434	366	113	-90	-271	-464	-611	-604	-377	-168	123	368
12	433	364	111	-92	-273	-466	-614	-606	-379	-170	121	368
13	429	363	110	-93	-275	-468	-616	-607	-380	-171	118	364
14	429	364	110	-93	-275	-469	-617	-609	-380	-170	120	364
15	435	366	112	-91	-274	-468	-616	-608	-377	-166	126	370
16	443	371	116	-88	-272	-466	-614	-604	-372	-159	133	377
17	443	376	122	-83	-269	-462	-610	-600	-364	-156	134	378
18	444	377	124	-79	-263	-456	-604	-594	-361	-154	135	378
19	445	378	126	-77	-260	-452	-600	-591	-359	-152	136	379
20	446	380	128	-75	-258	-449	-596	-588	-356	-150	137	380
21	447	381	129	-73	-255	-445	-593	-585	-353	-148	138	380
22	448	382	131	-70	-252	-441	-589	-582	-350	-145	140	381
23	451	385	134	-67	-249	-438	-585	-578	-346	-141	143	384

Direct Solar Gains (Wh) nVº

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	3	8	3	0	0	0	0	0
5	0	0	0	25	89	135	115	58	8	0	0	0
6	0	2	45	110	143	178	157	132	107	60	5	0
7	73	155	186	181	194	185	174	165	230	226	179	138
8	282	349	331	334	276	252	244	295	419	402	323	291
9	449	509	485	447	397	359	359	443	586	557	421	409
10	533	574	568	549	476	450	463	564	686	629	528	498
11	560	628	604	538	485	505	521	579	718	674	545	502
12	545	623	583	547	470	504	518	550	711	659	538	424
13	687	594	593	524	448	454	496	534	666	620	611	580
14	634	546	522	460	391	383	424	486	586	551	509	538
15	372	406	416	327	289	310	335	371	428	357	280	296
16	7	201	232	201	219	262	267	238	225	83	1	0
17	0	0	13	83	152	203	192	141	12	0	0	0
18	0	0	0	0	8	63	48	4	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh) nVº

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	3	43	72	105	93	72	3	0	0	0
1	0	0	0	0	2	33	24	1	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	3	1	0	0	0	0	0
6	0	0	0	9	34	55	45	21	3	0	0	0
7	0	1	18	53	80	109	95	73	46	16	2	0
8	12	31	63	100	120	150	144	124	98	59	29	14
9	46	73	107	159	167	200	200	178	161	105	60	46
10	82	116	156	190	208	235	246	222	209	147	91	76
11	103	139	181	219	229	266	276	255	238	170	118	96
12	115	157	191	207	225	276	276	249	247	184	126	104
13	112	157	184	222	293	372	373	291	244	176	119	89
14	130	144	221	288	324	420	411	356	306	204	122	102
15	133	196	256	309	305	382	384	366	350	238	157	128
16	161	220	254	293	289	332	353	342	329	232	154	133
17	145	202	231	251	255	292	309	294	277	194	127	123
18	145	163	171	195	202	242	243	231	205	169	135	128
19	130	153	150	136	132	161	162	154	172	151	122	112
20	116	137	134	133	123	134	135	139	169	154	123	96
21	162	146	151	142	130	137	146	149	179	161	154	142
22	165	147	149	141	129	133	144	156	181	161	143	146
23	110	123	135	120	119	129	136	142	157	120	88	88



Analysis Outputs (continued)

ANNUAL LOADS TABLE
MONTHLY AVERAGES (Wh)

nV¹

Inter-zonal Gains (Wh) nV¹

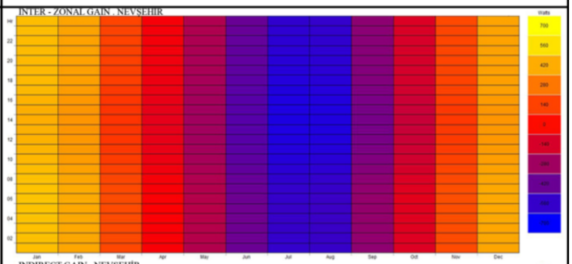
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	495	430	182	-18	-199	-385	-535	-532	-302	-98	187	428
1	499	434	186	-13	-193	-376	-527	-525	-294	-91	191	431
2	503	438	189	-11	-191	-373	-523	-522	-291	-88	196	436
3	504	439	192	-8	-188	-370	-520	-518	-286	-84	197	437
4	507	442	194	-6	-189	-371	-520	-517	-283	-81	201	440
5	508	443	195	-13	-220	-421	-566	-539	-286	-81	202	441
6	509	442	182	-38	-234	-447	-584	-562	-314	-96	199	441
7	497	421	159	-58	-247	-447	-591	-581	-342	-124	173	426
8	469	393	130	-89	-266	-461	-611	-605	-378	-156	147	399
9	447	373	111	-92	-280	-470	-624	-619	-393	-176	132	380
10	441	370	106	-105	-285	-482	-633	-633	-403	-183	116	371
11	434	358	100	-98	-283	-485	-633	-628	-409	-194	111	365
12	433	357	100	-112	-289	-487	-641	-633	-412	-194	111	372
13	413	360	97	-106	-288	-484	-639	-635	-404	-191	101	351
14	436	367	109	-96	-281	-478	-634	-631	-399	-181	126	375
15	456	383	119	-82	-271	-470	-624	-615	-379	-161	142	394
16	464	394	135	-71	-259	-458	-610	-600	-364	-147	148	398
17	456	397	141	-67	-261	-464	-612	-596	-358	-148	145	392
18	465	400	143	-57	-243	-446	-597	-582	-350	-140	154	400
19	473	407	151	-51	-237	-428	-580	-574	-340	-131	161	407
20	477	411	157	-45	-229	-419	-571	-566	-332	-124	165	410
21	480	415	162	-39	-222	-410	-561	-557	-324	-118	169	413
22	484	419	168	-33	-215	-400	-552	-549	-316	-111	174	416
23	489	424	174	-26	-207	-390	-542	-540	-307	-103	180	421

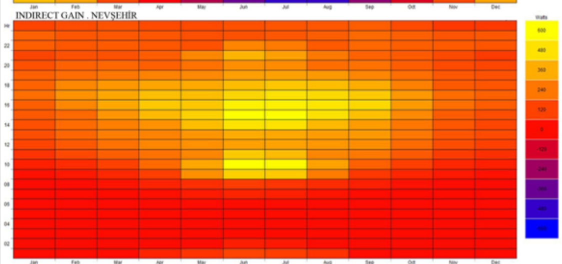
Direct Solar Gains (Wh) nV¹

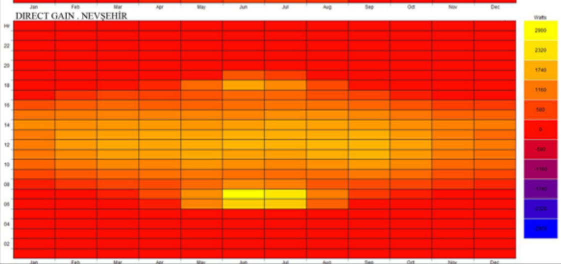
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	13	34	13	0	0	0	0	0
5	0	0	0	166	1299	2119	2053	904	34	0	0	0
6	0	9	194	673	1400	2823	2370	1218	485	198	22	0
7	184	423	610	681	1005	1366	1218	798	695	610	429	271
8	627	820	962	1060	1138	1074	1022	1034	1145	1007	727	628
9	955	1179	1345	1284	1470	1395	1309	1432	1544	1331	978	937
10	1141	1375	1579	1587	1700	1608	1602	1746	1793	1532	1236	1107
11	1208	1531	1684	1646	1718	1816	1787	1838	1833	1619	1313	1167
12	1188	1526	1588	1667	1628	1761	1753	1727	1760	1536	1237	1014
13	1368	1402	1506	1528	1497	1578	1691	1620	1550	1414	1269	1202
14	1120	1200	1275	1280	1292	1307	1417	1430	1327	1145	933	930
15	716	852	996	872	934	1051	1126	1084	957	763	524	497
16	29	400	602	567	767	982	976	708	593	185	2	0
17	0	0	53	274	1005	1643	1350	647	51	0	0	0
18	0	0	0	0	33	773	540	18	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh) nV¹

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	2	41	67	99	87	67	3	0	0	0
1	0	0	0	0	1	32	22	1	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	16	41	15	0	0	0	0	0
5	0	0	0	132	477	764	605	290	41	0	0	0
6	0	11	302	872	1258	1660	1459	1178	767	280	26	0
7	206	523	1065	1701	1998	2481	2387	2106	1701	1007	500	259
8	802	1268	1817	2722	2834	3441	3439	3077	2775	1795	1040	803
9	1426	1995	2696	3333	3582	4089	4280	3854	3692	2620	1564	1297
10	1904	2622	3320	3972	3996	4636	4809	4523	4433	3247	2287	1872
11	2425	3224	3688	3991	4074	4856	4925	4630	4876	3741	2650	2228
12	2638	3449	3803	4208	4160	4906	5042	4659	5024	3869	2683	2155
13	3096	3337	3820	4080	4109	4746	4923	4615	4705	3650	2905	2528
14	2669	3002	3430	3600	3731	4323	4519	4338	4285	3241	2301	2034
15	1858	2363	2833	2879	3167	3732	3876	3612	3414	2418	1595	1303
16	1196	1561	1997	2111	2398	2851	2965	2706	2263	1322	997	945
17	1036	898	918	1161	1430	1849	1848	1557	1039	880	806	871
18	607	646	626	511	472	719	714	584	658	564	470	506
19	111	359	358	288	233	278	285	312	351	207	97	89
20	81	106	119	152	180	202	208	183	147	117	88	68
21	119	109	115	117	120	146	148	132	139	124	117	106
22	128	115	119	114	106	115	122	128	148	130	115	115
23	90	101	113	102	104	113	118	122	135	101	73	72







Analysis Outputs (continued)

ANNUAL LOADS TABLE

MONTHLY AVERAGES (Wh)

nV²

Inter-zonal Gains (Wh) nV²

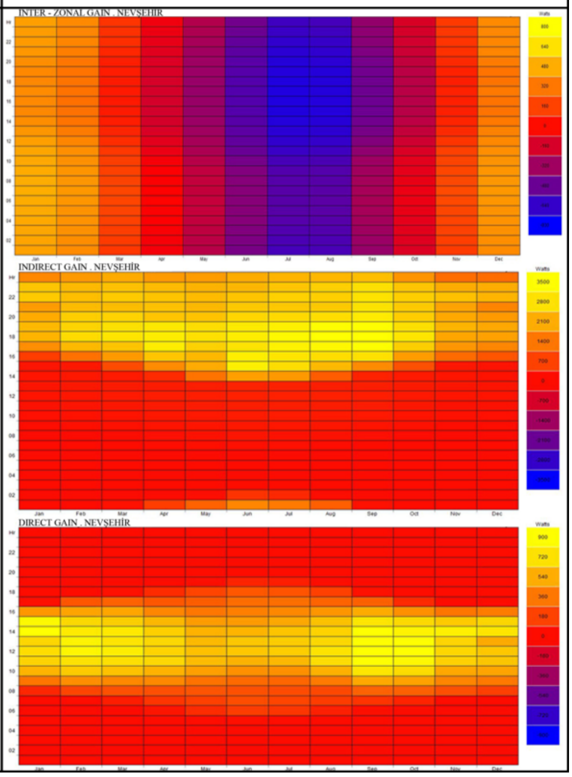
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	453	386	130	-75	-268	-467	-615	-602	-359	-148	146	389
1	459	392	138	-60	-249	-444	-593	-581	-347	-138	153	395
2	465	398	146	-52	-238	-429	-577	-568	-336	-128	160	401
3	470	404	154	-43	-228	-416	-564	-557	-324	-119	167	406
4	475	409	162	-35	-218	-405	-552	-545	-314	-110	174	411
5	481	415	169	-29	-213	-399	-545	-537	-304	-101	180	416
6	486	420	173	-26	-209	-394	-539	-532	-300	-96	186	420
7	487	418	172	-27	-208	-392	-537	-531	-301	-97	184	420
8	479	411	165	-35	-214	-398	-544	-539	-312	-107	176	413
9	476	408	162	-36	-214	-398	-544	-540	-314	-109	174	411
10	474	407	160	-39	-216	-399	-546	-543	-317	-112	173	410
11	473	405	159	-39	-217	-400	-547	-544	-318	-113	171	409
12	474	405	159	-39	-218	-404	-550	-544	-317	-112	172	411
13	471	406	159	-43	-236	-429	-574	-556	-319	-112	171	409
14	472	406	148	-67	-256	-459	-600	-585	-345	-125	172	410
15	469	391	128	-88	-269	-474	-616	-606	-373	-147	154	401
16	452	370	110	-107	-284	-484	-632	-624	-395	-167	137	387
17	431	356	96	-116	-297	-496	-646	-636	-408	-186	121	368
18	419	348	86	-122	-302	-502	-652	-645	-418	-198	105	354
19	414	341	82	-120	-303	-504	-653	-645	-421	-205	98	349
20	412	339	81	-123	-304	-505	-655	-645	-425	-210	93	350
21	399	336	77	-124	-305	-505	-657	-646	-426	-211	85	338
22	401	339	81	-120	-302	-499	-652	-644	-422	-205	93	341
23	420	350	91	-108	-293	-491	-643	-634	-406	-186	116	362

Direct Solar Gains (Wh) nV²

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	4	10	4	0	0	0	0	0
5	0	0	0	31	108	164	139	70	10	0	0	0
6	0	3	56	136	175	216	191	162	133	75	6	0
7	91	194	231	224	240	229	215	204	287	283	224	173
8	353	437	412	417	342	311	303	368	524	502	404	364
9	563	637	606	559	493	445	446	552	733	697	527	512
10	669	719	710	685	592	559	576	703	858	788	661	624
11	702	786	754	670	603	627	649	722	898	843	682	629
12	683	780	728	681	585	627	644	685	889	825	674	531
13	862	744	741	653	558	564	617	666	833	775	765	727
14	796	684	653	574	486	475	527	606	733	690	639	675
15	467	509	520	408	359	386	417	462	536	447	351	371
16	8	252	289	251	273	326	332	296	280	104	1	0
17	0	0	15	103	188	251	237	175	15	0	0	0
18	0	0	0	0	10	78	59	5	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh) nV²

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	65	644	1122	1589	1441	1076	66	0	0	0
1	0	0	0	0	40	506	366	21	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	3	1	0	0	0	0	0
6	0	0	0	9	34	55	45	21	3	0	0	0
7	0	1	18	53	80	109	95	73	46	16	2	0
8	12	31	63	100	120	150	144	124	98	59	29	14
9	46	73	107	159	167	200	200	178	161	105	60	46
10	82	116	156	190	208	235	246	222	209	147	91	76
11	103	139	181	219	229	266	276	255	238	170	118	96
12	115	157	191	207	240	314	291	249	247	184	126	104
13	112	157	185	400	1360	1930	1838	1036	284	176	119	89
14	130	155	850	1674	2072	2983	2729	2270	1662	890	148	102
15	634	1323	1863	2422	2243	2956	2831	2732	2772	1892	1243	957
16	1709	2276	2419	2937	2570	2810	2984	3080	3306	2532	1818	1585
17	2200	2702	2839	2935	2763	2935	3090	3177	3455	2830	2005	1940
18	2274	2615	2784	2876	2730	2898	2979	3167	3298	2750	2191	2038
19	2078	2526	2584	2409	2391	2636	2673	2725	2900	2521	2036	1850
20	1876	2286	2304	2367	2250	2460	2456	2472	2788	2490	1989	1572
21	2487	2342	2478	2408	2283	2408	2573	2552	2813	2533	2362	2189
22	2413	2268	2357	2283	2178	2236	2426	2554	2764	2415	2088	2099
23	1618	1837	2074	1853	1896	2085	2206	2234	2326	1779	1271	1254



Analysis Outputs (continued)

ANNUAL LOADS TABLE

MONTHLY AVERAGES (Wh)

nV^3

Inter-zonal Gains (Wh) — nV^3

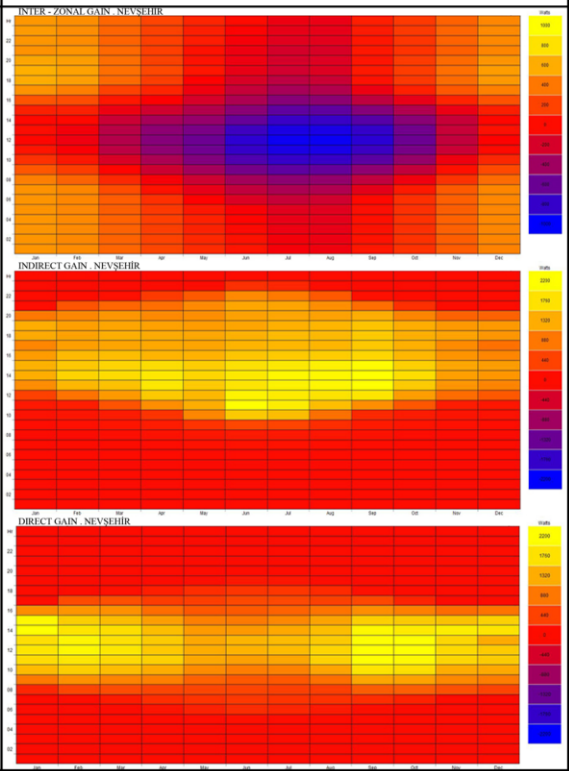
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	468	402	153	-48	-232	-420	-566	-558	-325	-122	161	400
1	470	404	156	-45	-227	-415	-561	-553	-321	-118	163	402
2	472	407	158	-42	-225	-411	-558	-550	-318	-115	166	405
3	474	409	160	-40	-222	-408	-555	-547	-315	-113	168	407
4	476	410	162	-38	-221	-407	-553	-545	-312	-110	170	408
5	477	411	163	-40	-226	-414	-559	-548	-312	-109	172	410
6	478	412	160	-47	-232	-421	-565	-556	-320	-114	172	410
7	473	402	150	-55	-239	-429	-573	-564	-332	-126	160	402
8	459	389	138	-68	-250	-441	-586	-578	-348	-141	148	391
9	447	377	125	-80	-261	-453	-599	-592	-364	-155	138	381
10	438	369	116	-90	-269	-461	-608	-603	-376	-166	127	371
11	432	362	109	-94	-274	-468	-615	-609	-384	-174	120	366
12	429	358	106	-97	-277	-472	-619	-611	-388	-178	117	366
13	421	358	104	-98	-278	-473	-622	-613	-387	-178	112	358
14	423	360	106	-96	-278	-472	-621	-613	-386	-175	116	360
15	434	366	110	-91	-273	-469	-617	-609	-379	-167	127	371
16	450	375	119	-84	-269	-465	-613	-602	-369	-154	140	384
17	451	385	129	-77	-265	-459	-608	-595	-357	-148	141	385
18	453	386	132	-71	-257	-451	-599	-587	-353	-145	143	386
19	455	388	135	-68	-253	-446	-593	-583	-349	-142	145	388
20	457	391	138	-65	-250	-442	-589	-579	-345	-139	147	390
21	458	392	141	-61	-246	-437	-584	-574	-341	-136	149	391
22	460	394	143	-58	-242	-431	-578	-570	-336	-132	152	393
23	463	397	147	-54	-237	-425	-573	-565	-331	-127	156	396

Direct Solar Gains (Wh) — nV^3

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	8	19	7	0	0	0	0	0
5	0	0	0	60	177	261	211	113	20	0	0	0
6	0	5	112	269	322	351	315	299	270	169	13	0
7	222	464	521	477	477	456	428	409	663	678	554	446
8	891	1087	966	951	701	618	615	814	1252	1229	1013	922
9	1433	1588	1444	1315	1053	929	959	1249	1770	1723	1313	1280
10	1698	1779	1686	1610	1288	1215	1270	1615	2079	1941	1646	1571
11	1780	1935	1790	1546	1316	1361	1435	1644	2188	2085	1685	1567
12	1725	1919	1741	1571	1280	1376	1432	1564	2154	2019	1663	1301
13	2149	1782	1725	1451	1166	1159	1288	1454	1940	1823	1847	1775
14	1928	1589	1454	1210	949	900	1016	1239	1602	1560	1495	1619
15	1060	1130	1091	786	611	630	707	845	1068	940	779	853
16	17	522	548	400	405	494	502	436	492	193	1	0
17	0	0	31	142	272	338	340	246	29	0	0	0
18	0	0	0	0	19	96	77	10	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh) — nV^3

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	4	52	87	126	112	86	4	0	0	0
1	0	0	0	0	2	40	28	1	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	3	1	0	0	0	0	0
6	0	0	0	9	33	53	44	21	3	0	0	0
7	0	1	17	52	79	109	94	71	45	16	2	0
8	12	30	61	115	296	439	428	247	98	57	28	13
9	44	71	117	210	345	597	533	336	190	113	59	44
10	88	134	186	228	273	423	391	272	241	174	107	82
11	125	170	226	272	295	329	335	310	289	211	144	117
12	147	202	252	267	307	355	348	322	315	237	163	139
13	152	212	258	300	401	481	478	389	324	239	167	130
14	173	207	308	389	442	555	539	477	403	279	177	148
15	183	273	349	420	419	513	511	486	456	319	218	180
16	222	300	345	401	396	450	478	458	426	313	216	191
17	195	274	314	343	354	395	419	398	363	262	172	164
18	188	218	240	264	279	329	335	316	273	222	170	157
19	149	189	201	186	227	291	285	216	225	179	139	127
20	130	154	156	181	273	378	331	241	195	174	139	108
21	183	166	174	165	155	269	245	175	205	184	175	161
22	187	168	173	165	152	157	171	183	210	186	164	165
23	127	142	158	141	142	154	163	168	184	140	101	101



Analysis Outputs (continued)

ANNUAL LOADS TABLE

MONTHLY AVERAGES (Wh) nV^P

Inter-zonal Gains (Wh) nV^P

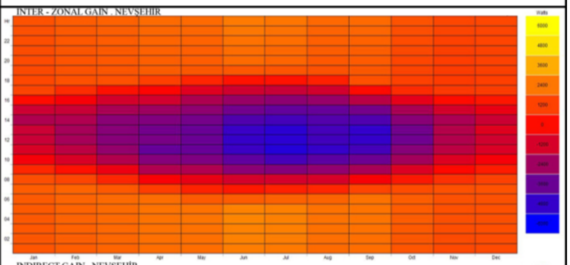
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	1599	1813	1961	2167	2165	2533	2436	2109	2136	1618	1359	1378
1	1642	1857	2012	2228	2233	2616	2520	2189	2209	1683	1410	1423
2	1684	1899	2048	2259	2268	2663	2568	2231	2251	1725	1459	1468
3	1707	1920	2078	2288	2296	2696	2601	2267	2293	1762	1485	1491
4	1730	1943	2102	2307	2282	2651	2590	2285	2324	1790	1513	1515
5	1746	1959	2111	2140	1731	1759	1899	1950	2271	1802	1533	1531
6	1755	1945	1704	1088	481	257	476	573	1244	1409	1491	1535
7	1472	1272	567	-372	-748	-1259	-1234	-1167	-409	269	815	1188
8	590	93	-673	-2056	-2047	-2869	-3022	-2748	-2222	-1056	-95	336
9	-477	-1127	-2009	-3003	-3152	-3804	-4404	-3904	-3557	-2336	-1005	-443
10	-1124	-1755	-2667	-3730	-3667	-4662	-5128	-4783	-4427	-2971	-1762	-1108
11	-1496	-2247	-2954	-3254	-3591	-4746	-5014	-4511	-4800	-3483	-2007	-1326
12	-1439	-2280	-2931	-3435	-3636	-4679	-5000	-4417	-4818	-3405	-1940	-994
13	-2069	-2047	-2906	-3109	-3376	-4176	-4447	-4097	-4204	-2923	-2161	-1469
14	-1406	-1489	-2203	-2444	-2786	-3416	-3750	-3690	-3338	-2202	-1264	-750
15	-23	-465	-1236	-1315	-2081	-2569	-2839	-2601	-1847	-843	-22	228
16	1253	710	96	-189	-959	-1345	-1539	-1286	-51	706	992	1103
17	1315	1522	1488	1142	550	124	135	447	1511	1161	1025	1122
18	1344	1553	1603	1779	1668	1663	1620	1572	1655	1217	1060	1146
19	1382	1587	1656	1836	1783	2077	1961	1676	1734	1280	1100	1178
20	1418	1627	1712	1896	1857	2170	2058	1762	1816	1344	1143	1209
21	1454	1666	1767	1956	1932	2265	2152	1847	1897	1409	1188	1241
22	1496	1709	1825	2020	2008	2364	2253	1936	1982	1480	1240	1279
23	1542	1755	1887	2091	2088	2464	2356	2027	2073	1556	1297	1321

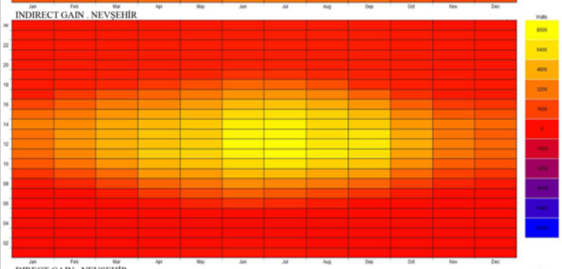
Direct Solar Gains (Wh) nV^P

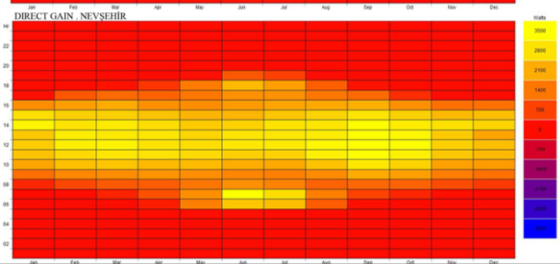
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	19	49	18	0	0	0	0	0
5	0	0	0	217	1505	2439	2334	1040	50	0	0	0
6	0	14	282	889	1702	3238	2731	1493	697	326	32	0
7	348	769	1006	1050	1383	1727	1557	1121	1194	1115	837	595
8	1280	1620	1686	1781	1692	1564	1510	1661	2078	1916	1470	1302
9	2002	2345	2422	2268	2283	2118	2049	2380	2860	2600	1942	1877
10	2383	2686	2837	2794	2690	2541	2574	2966	3336	2964	2446	2257
11	2509	2957	3020	2811	2729	2864	2885	3083	3453	3155	2553	2319
12	2450	2942	2885	2852	2619	2817	2847	2909	3393	3066	2489	1987
13	3036	2804	2895	2727	2497	2578	2789	2837	3165	2916	2769	2613
14	2746	2556	2564	2401	2216	2214	2424	2611	2837	2567	2262	2327
15	1699	1913	2076	1733	1689	1860	1987	2052	2133	1725	1280	1298
16	42	962	1224	1138	1398	1723	1732	1401	1220	425	3	0
17	0	0	78	530	1440	2257	1906	1070	76	0	0	0
18	0	0	0	0	48	969	683	26	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh) nV^P

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	12	139	245	355	317	235	13	0	0	0
1	0	0	0	0	7	113	81	4	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	25	64	24	0	0	0	0	0
5	0	0	1	204	713	1150	901	429	64	0	0	0
6	0	18	447	1305	1932	2544	2230	1763	1149	411	41	0
7	306	783	1618	2616	3090	3849	3709	3258	2608	1533	749	377
8	1212	1931	2807	4164	4285	5238	5227	4693	4293	2778	1589	1224
9	2205	3089	4059	5034	5367	6162	6492	5836	5528	3897	2417	2002
10	2773	3681	4717	5769	5894	6923	7225	6705	6301	4473	3103	2534
11	3058	4114	4960	5406	5790	7125	7205	6500	6554	4840	3294	2731
12	2967	4099	4805	5496	5705	6957	7105	6263	6441	4662	3125	2352
13	3489	3793	4687	5158	5609	6710	6902	6071	5770	4190	3258	2726
14	2790	3221	4110	4701	5138	6128	6329	5854	5225	3567	2335	1982
15	1658	2404	3349	3639	4331	5230	5389	4836	4031	2486	1381	1156
16	461	1363	2155	2630	3255	3983	4092	3569	2509	1033	413	354
17	395	558	744	1320	1966	2690	2622	1970	896	570	374	343
18	401	476	545	616	713	1157	1069	763	654	506	389	348
19	342	436	483	481	505	603	599	560	545	431	337	298
20	278	364	411	451	468	521	517	498	493	400	304	248
21	331	366	419	452	471	518	542	510	484	400	336	300
22	331	347	393	418	439	481	507	494	475	384	307	291
23	241	291	358	348	387	446	459	438	420	296	195	183







Analysis Outputs (continued)

ANNUAL LOADS TABLE
MONTHLY AVERAGES (Wh)

nP

Inter-zonal Gains (Wh) nP

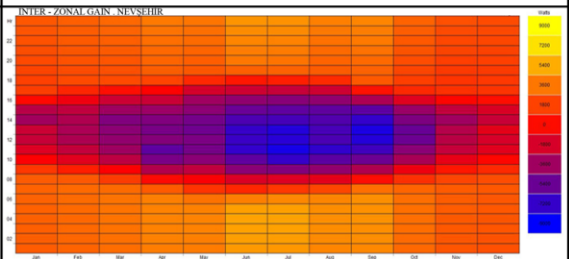
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	2651	2905	3242	3779	3724	4718	4688	4046	4173	3057	2396	2257
1	2734	3007	3369	3917	3881	4910	4879	4227	4344	3194	2489	2340
2	2781	3083	3424	3972	3954	5008	4984	4312	4395	3239	2554	2400
3	2820	3085	3440	3996	3977	5055	5017	4346	4426	3286	2595	2440
4	2851	3121	3472	3995	3923	4979	4959	4321	4460	3317	2635	2476
5	2876	3135	3462	3880	3380	3889	4147	4014	4394	3313	2665	2502
6	2883	3113	3135	2601	1333	904	1478	1948	3271	2953	2610	2497
7	2642	2567	1609	-67	-524	-1653	-1542	-1313	34	1243	1895	2168
8	1443	614	-442	-2989	-2515	-4357	-4596	-4079	-3097	-986	359	952
9	-445	-1431	-2616	-4878	-4300	-5735	-7170	-5864	-5312	-3294	-1168	-186
10	-1563	-2391	-3626	-5806	-4970	-7277	-8215	-7287	-6782	-4313	-2374	-1407
11	-2292	-3129	-4063	-4551	-4836	-7041	-7617	-6457	-7712	-5349	-2720	-1753
12	-2209	-3250	-4317	-4933	-5259	-7144	-7780	-6592	-8051	-5470	-2882	-1297
13	-3567	-3100	-4657	-4661	-5055	-6397	-6596	-6230	-7277	-4735	-3612	-2291
14	-2802	-2484	-3661	-3792	-4268	-5423	-5770	-5769	-5845	-3877	-2446	-1645
15	-153	-903	-2124	-2230	-3610	-4154	-4410	-4147	-3229	-1456	-251	19
16	1645	882	138	-348	-1815	-2095	-2332	-2072	241	968	1220	1341
17	1743	2002	2061	1831	927	347	612	990	2559	1686	1335	1426
18	1869	2151	2252	2754	2503	2864	2886	2663	2866	1912	1512	1553
19	2034	2309	2443	2954	2723	3541	3455	2922	3132	2144	1679	1689
20	2172	2453	2629	3133	2935	3797	3726	3160	3383	2362	1833	1808
21	2302	2572	2789	3297	3143	4051	3981	3399	3607	2550	1981	1924
22	2409	2679	2933	3442	3334	4294	4231	3618	3812	2728	2107	2019
23	2503	2776	3081	3610	3535	4553	4493	3842	4039	2914	2238	2100

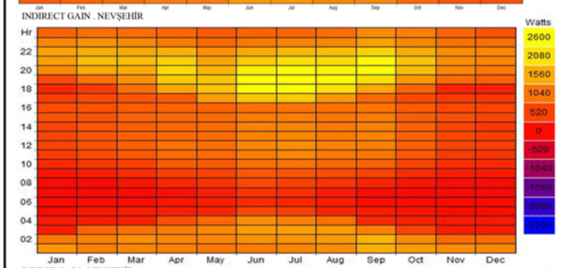
Direct Solar Gains (Wh) nP

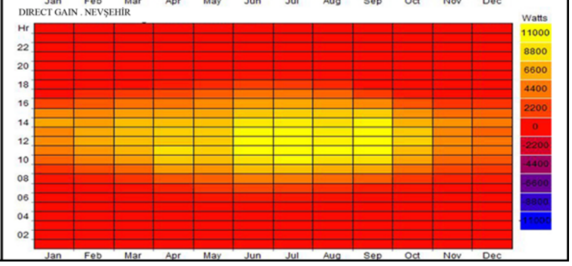
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	19	48	18	0	0	0	0	0
5	0	0	0	146	407	594	469	258	49	0	0	0
6	0	13	282	900	1793	2400	2027	1464	714	340	31	0
7	366	819	1699	3052	3544	4655	4578	3934	3298	1863	911	641
8	1659	2755	3724	5988	5560	7317	7409	6737	6462	4058	2386	1847
9	3624	4847	6004	7824	7344	8782	9774	8697	8803	6328	3812	3023
10	4708	5883	7055	8892	8118	10261	10953	10140	10199	7292	5044	4163
11	5323	6626	7429	7847	7918	10225	10635	9526	10853	8091	5262	4365
12	5110	6580	7391	8092	8011	10126	10587	9359	10835	7891	5150	3612
13	6396	6124	7414	7521	7542	9118	9385	8710	9723	6896	5638	4654
14	5204	5155	6112	6347	6436	7750	8112	7867	8014	5610	4026	3624
15	2299	3212	4282	4402	5267	6217	6502	5925	5179	2975	1677	1633
16	42	1181	1901	2392	3343	4248	4347	3628	1990	510	3	0
17	0	0	76	547	1164	2056	1892	1107	75	0	0	0
18	0	0	0	0	47	317	244	25	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh) nP

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	1334	1134	1177	1133	1038	1102	1174	1279	1593	1403	1255	1226
1	1049	1137	1267	1187	1182	1300	1329	1388	1637	1229	916	902
2	166	831	959	1088	1225	1393	1431	1388	1136	536	163	150
3	137	156	199	656	889	1263	1122	971	263	175	118	111
4	2	111	141	171	231	582	485	231	165	60	0	0
5	0	0	3	98	183	289	239	172	4	0	0	0
6	0	0	0	31	187	394	332	123	8	0	0	0
7	0	2	91	254	388	586	514	382	227	97	5	0
8	75	176	307	499	529	740	707	623	537	314	177	123
9	280	403	504	808	1050	1413	1419	1094	820	525	333	276
10	454	587	852	1257	1371	1842	1848	1547	1309	856	453	389
11	623	865	1117	1429	1412	1843	1863	1676	1579	1088	737	608
12	810	1052	1213	1380	1383	1676	1733	1599	1663	1221	823	701
13	830	1079	1243	1368	1424	1685	1725	1573	1655	1228	833	679
14	963	1034	1270	1341	1404	1590	1623	1542	1578	1174	913	794
15	880	1026	1203	1242	1278	1454	1482	1454	1459	1111	863	785
16	713	933	1069	1214	1852	2265	2273	1793	1311	980	711	636
17	588	847	1385	1970	2211	2951	2864	2536	2006	1288	578	533
18	953	1386	1709	2297	2248	3072	3032	2843	2576	1788	1267	1129
19	1520	1902	1993	2409	2061	2705	2852	2752	2854	2098	1465	1311
20	1506	2001	2049	2251	1885	2334	2538	2457	2657	1983	1336	1222
21	1560	1629	1601	1804	1580	1987	2061	2041	2013	1624	1336	1283
22	1288	1369	1262	1113	948	1226	1296	1244	1485	1268	1043	1040
23	895	998	967	913	792	871	901	976	1290	1165	919	749







Analysis Outputs (continued)

ANNUAL LOADS TABLE

MONTHLY AVERAGES (Wh)

vV°

Inter-zonal Gains (Wh)

vV°

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	700	601	225	-80	-355	-638	-860	-849	-497	-190	236	598
1	703	603	228	-76	-351	-634	-855	-845	-493	-186	239	601
2	706	607	231	-73	-348	-630	-851	-841	-489	-182	243	605
3	708	609	233	-71	-346	-627	-848	-838	-486	-179	246	607
4	710	611	235	-69	-346	-627	-848	-836	-483	-177	248	609
5	712	612	236	-72	-353	-639	-858	-842	-484	-176	250	610
6	712	612	230	-84	-365	-652	-871	-856	-498	-184	249	611
7	707	602	213	-100	-379	-668	-886	-872	-521	-204	233	598
8	681	573	192	-123	-393	-684	-903	-893	-550	-233	206	577
9	657	550	170	-143	-412	-702	-925	-917	-576	-259	187	557
10	641	537	154	-159	-426	-719	-943	-936	-595	-276	169	540
11	631	526	144	-163	-433	-729	-954	-945	-608	-289	159	533
12	627	521	140	-167	-436	-734	-959	-948	-614	-294	154	534
13	614	521	137	-167	-437	-732	-959	-948	-612	-293	146	521
14	616	525	142	-162	-433	-727	-953	-944	-604	-287	154	523
15	639	537	152	-150	-424	-718	-945	-934	-588	-268	175	544
16	669	556	169	-136	-416	-711	-936	-919	-568	-244	200	570
17	674	573	187	-124	-408	-702	-926	-909	-549	-232	206	574
18	677	578	193	-115	-397	-689	-913	-896	-540	-225	210	577
19	681	581	198	-109	-389	-680	-903	-888	-533	-219	214	581
20	685	585	204	-103	-383	-671	-895	-880	-525	-213	219	585
21	689	589	209	-97	-376	-663	-886	-872	-517	-206	223	588
22	692	593	214	-92	-369	-654	-877	-864	-510	-201	227	591
23	696	596	219	-86	-362	-645	-868	-857	-502	-195	231	594

Direct Solar Gains (Wh)

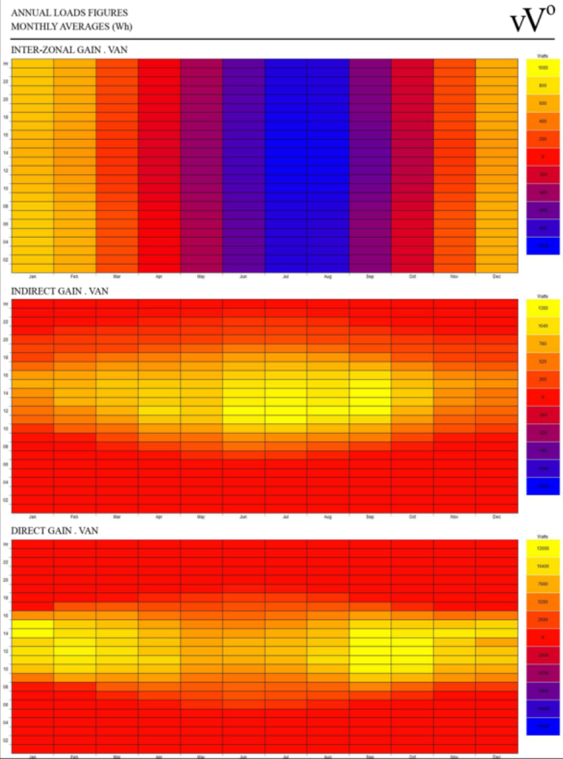
vV°

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	41	105	39	0	0	0	0	0
5	0	0	1	371	1494	2136	1871	1006	106	0	0	0
6	0	29	1151	2409	2762	3402	3121	2933	2563	1498	68	0
7	405	1193	3831	4422	3731	4178	4015	4233	5860	4123	2122	2216
8	5087	7294	6658	7134	5160	5040	5258	6500	9061	8137	6540	5790
9	8942	10048	9201	8807	6947	6606	7109	8550	11455	10752	8063	7829
10	10199	10711	10176	9904	7851	7895	8312	10077	12629	11553	9696	9308
11	10347	11280	10344	8932	7636	8098	8587	9619	12712	11971	9651	8980
12	9848	10878	9900	9011	7399	8074	8388	9091	12481	11655	9543	7444
13	12508	10343	10096	8536	6993	7063	7767	8643	11599	10757	10852	10381
14	11511	9444	8738	7407	5925	5750	6445	7727	9958	9514	9061	9762
15	6482	6931	6848	5184	4258	4361	4882	5693	7100	5985	4850	5265
16	90	3394	3636	3070	2875	3343	3450	3489	3456	1345	7	0
17	0	0	166	1093	1804	2318	2268	1742	161	0	0	0
18	0	0	0	0	103	635	495	55	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh)

vV°

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	2	6	2	0	0	0	0	0
6	0	0	0	24	141	215	190	94	6	0	0	0
7	0	2	101	249	332	476	427	351	237	75	4	0
8	24	62	286	480	464	633	618	585	541	280	61	28
9	175	403	474	704	701	909	943	835	758	502	323	232
10	429	554	690	903	885	1112	1176	1043	999	692	413	356
11	493	616	811	1024	929	1177	1219	1162	1172	809	506	434
12	573	807	873	942	908	1105	1155	1089	1200	912	635	523
13	649	814	881	954	925	1093	1140	1058	1198	932	642	509
14	786	793	907	918	910	1041	1070	1039	1135	874	723	639
15	702	730	812	811	825	930	970	966	1007	782	606	560
16	451	570	671	672	735	833	855	821	808	589	411	363
17	258	410	500	545	611	708	726	671	560	349	251	227
18	268	254	276	361	423	533	529	461	321	277	242	241
19	181	215	242	231	244	312	312	275	277	210	150	147
20	26	133	166	176	204	238	245	226	173	80	17	12
21	2	15	34	94	141	200	181	144	35	8	0	0
22	0	0	4	12	28	78	66	23	3	0	0	0
23	0	0	0	0	2	8	7	1	0	0	0	0



Analysis Outputs (continued)

ANNUAL LOADS TABLE
MONTHLY AVERAGES (Wh)

vV1

Inter-zonal Gains (Wh)

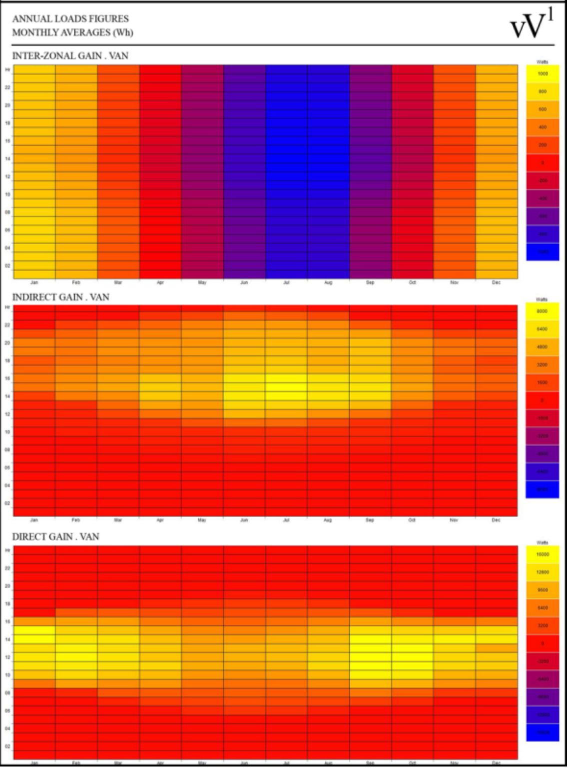
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	726	625	246	-60	-338	-626	-848	-835	-478	-166	264	625
1	732	631	254	-52	-328	-614	-836	-823	-468	-156	271	630
2	738	637	261	-44	-319	-603	-824	-813	-458	-147	278	637
3	743	642	268	-37	-311	-593	-814	-803	-448	-139	284	642
4	748	647	273	-32	-307	-588	-809	-797	-441	-132	290	647
5	753	651	278	-31	-312	-597	-815	-798	-437	-127	295	651
6	756	654	273	-43	-323	-608	-825	-811	-450	-133	298	655
7	752	645	256	-55	-336	-623	-840	-825	-471	-154	280	641
8	721	610	232	-82	-351	-640	-858	-848	-504	-187	250	616
9	693	583	206	-109	-386	-678	-898	-885	-536	-217	229	594
10	673	567	177	-149	-420	-723	-942	-932	-583	-247	207	575
11	658	547	150	-172	-437	-747	-969	-961	-623	-281	186	561
12	640	516	132	-189	-449	-758	-985	-973	-642	-304	157	548
13	605	509	120	-191	-454	-759	-990	-976	-646	-311	139	517
14	605	512	125	-184	-450	-754	-983	-974	-637	-307	144	515
15	635	528	138	-165	-439	-741	-969	-957	-615	-284	170	543
16	675	552	158	-152	-430	-736	-962	-944	-595	-259	198	575
17	669	568	173	-142	-428	-732	-958	-937	-580	-252	194	570
18	666	567	175	-137	-419	-723	-949	-930	-578	-251	195	568
19	676	572	179	-131	-415	-716	-941	-923	-569	-238	210	581
20	699	585	194	-119	-406	-705	-931	-912	-545	-213	233	601
21	706	604	217	-100	-386	-686	-909	-889	-516	-196	240	607
22	712	611	226	-82	-364	-659	-882	-863	-502	-185	248	612
23	719	617	236	-72	-352	-640	-864	-849	-488	-174	255	618

Direct Solar Gains (Wh)

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	50	129	48	0	0	0	0	0
5	0	0	1	445	1699	2436	2107	1136	131	0	0	0
6	0	36	1291	2745	3153	3808	3489	3299	2834	1585	83	0
7	499	1426	4337	4631	4329	4748	4550	4699	6360	4771	2481	2519
8	6199	8685	7801	8143	5976	5814	5989	7323	10521	9715	7907	7035
9	10930	12178	11028	10432	8206	7667	8157	10006	13737	13110	9892	9635
10	12662	13199	12463	12008	9493	9337	9816	12142	15441	14301	12088	11584
11	12981	14031	12852	11035	9337	9818	10429	11809	15802	14989	12111	11272
12	12430	13721	12428	11207	9124	9926	10335	11236	15639	14659	12062	9388
13	15826	13037	12627	10631	8613	8669	9546	10686	14538	13512	13708	13111
14	14499	11855	10947	9205	7264	7008	7882	9551	12434	11937	11422	12357
15	8157	8729	8535	6381	5213	5079	5794	6906	8829	7484	6104	6611
16	111	4233	4503	3769	3268	3833	3947	4202	4233	1668	9	0
17	0	0	204	1218	2068	2621	2593	1967	197	0	0	0
18	0	0	0	0	127	716	566	67	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh)

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	2	6	2	0	0	0	0	0
6	0	0	0	26	160	240	216	107	6	0	0	0
7	0	2	115	278	364	525	473	392	265	83	4	0
8	24	62	311	524	498	684	669	638	592	303	61	28
9	185	433	505	747	736	963	994	882	806	533	344	247
10	452	583	717	1058	2010	2803	2759	1830	1048	718	431	373
11	509	638	1603	2955	3486	5081	4732	4007	2979	1353	526	444
12	631	945	2752	4513	4228	5999	5983	5661	5187	2672	755	580
13	1486	3239	3829	5627	4878	6552	6983	6446	6235	3938	2429	1703
14	3049	3883	4571	5788	5190	6513	7359	6478	6445	4486	2836	2378
15	3024	3689	4350	5399	4909	6496	6957	6311	6130	4200	2846	2425
16	2568	3333	3816	4056	4209	5575	5829	5090	5459	3777	2362	1949
17	2129	2890	3464	3979	4154	5291	5482	4782	5344	3746	2341	1605
18	3206	3071	3842	4070	4259	5160	5260	4837	5373	3810	3111	2494
19	3233	3113	3760	3962	4050	4917	5105	4933	5296	3816	2859	2533
20	1860	2497	3265	3452	4048	4760	4816	4527	4350	2625	1546	1454
21	14	1354	1897	2567	3388	4087	4155	3697	2228	712	1	0
22	0	0	26	1052	1619	2681	2325	1754	37	0	0	0
23	0	0	0	0	16	614	423	9	0	0	0	0



Analysis Outputs (continued)

ANNUAL LOADS TABLE
MONTHLY AVERAGES (Wh)

vV²

Inter-zonal Gains (Wh)

vV²

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	739	642	271	-29	-301	-576	-799	-792	-442	-140	279	636
1	745	648	277	-22	-294	-568	-789	-783	-433	-131	287	643
2	754	655	284	-16	-288	-560	-782	-776	-425	-122	296	652
3	757	660	290	-10	-283	-554	-776	-769	-416	-116	301	656
4	761	664	294	-6	-281	-553	-773	-764	-411	-111	305	659
5	764	667	296	-13	-315	-607	-823	-788	-412	-109	308	662
6	765	667	282	-42	-338	-644	-852	-820	-445	-127	306	663
7	755	645	249	-69	-348	-648	-858	-837	-486	-164	276	641
8	712	596	213	-107	-374	-660	-879	-873	-533	-212	231	604
9	670	560	177	-136	-403	-689	-911	-908	-573	-252	201	570
10	645	539	153	-161	-425	-714	-939	-938	-602	-278	172	545
11	632	523	139	-166	-434	-729	-955	-950	-619	-297	157	533
12	627	516	134	-172	-437	-736	-961	-953	-626	-304	149	537
13	606	516	131	-171	-438	-733	-962	-953	-623	-302	138	516
14	612	523	139	-161	-431	-723	-953	-947	-611	-291	153	523
15	647	545	156	-141	-417	-712	-941	-930	-584	-260	188	558
16	698	577	184	-121	-409	-709	-934	-909	-553	-218	231	601
17	705	606	216	-101	-401	-705	-925	-896	-519	-200	238	606
18	708	609	224	-83	-366	-670	-890	-865	-507	-192	241	608
19	712	613	230	-74	-355	-642	-866	-852	-496	-184	247	612
20	717	619	238	-66	-345	-629	-853	-840	-484	-175	253	616
21	722	625	247	-56	-333	-615	-838	-827	-472	-165	259	621
22	728	631	255	-48	-322	-600	-824	-814	-461	-156	265	626
23	732	636	262	-39	-312	-587	-810	-802	-449	-147	271	629

Direct Solar Gains (Wh)

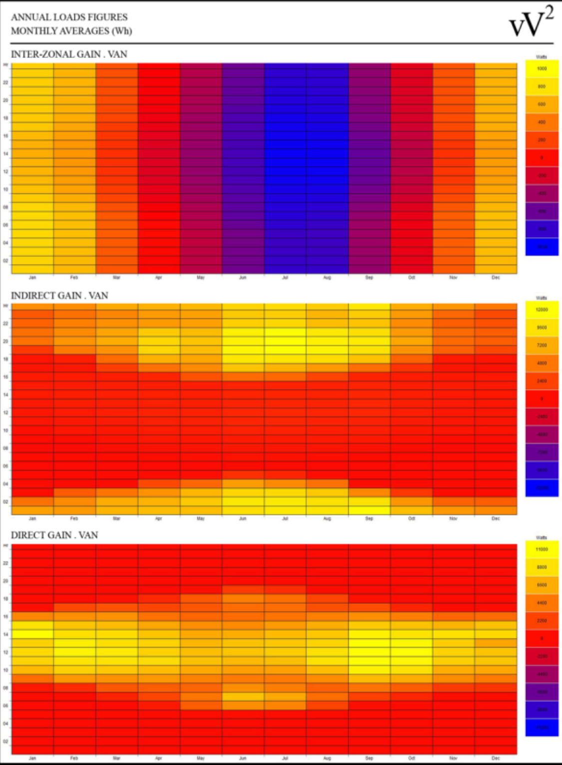
vV²

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	47	120	45	0	0	0	0	0
5	0	0	1	522	3346	5274	4972	2301	122	0	0	0
6	0	33	912	2342	4305	7462	6417	3987	2107	1093	78	0
7	476	1259	3126	3377	3635	5362	4657	3442	4280	3329	1829	1684
8	3981	5740	5485	5746	4777	4527	4520	5254	7109	6544	5191	4495
9	7082	8076	7705	7237	6407	5976	6070	7253	9336	8755	6593	6388
10	8191	8859	8768	8526	7391	7106	7324	8800	10539	9612	8026	7596
11	8423	9503	9097	8080	7319	7623	7865	8724	10737	10014	8128	7501
12	8115	9275	8678	8139	6972	7479	7666	8192	10431	9669	7945	6296
13	9927	8643	8538	7537	6434	6571	7170	7668	9384	8805	8692	8351
14	8776	7632	7240	6319	5376	5214	5813	6651	7852	7459	6926	7437
15	4994	5439	5514	4191	3627	3891	4269	4703	5382	4617	3670	3901
16	104	2513	2921	2389	3069	3985	3930	2753	2712	991	9	0
17	0	0	190	1121	3106	4669	4058	2384	185	0	0	0
18	0	0	0	0	118	1914	1363	63	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh)

vV²

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	6685	6330	7533	7940	8024	9419	9853	9701	10641	7977	6219	5582
1	4567	5627	7158	7407	8472	9860	9928	9522	9584	6167	3871	3646
2	39	3483	4686	6013	7626	8995	9194	8396	5518	1858	3	0
3	0	0	72	2773	4107	6422	5606	4496	99	0	0	0
4	0	0	0	0	44	1611	1110	24	0	0	0	0
5	0	0	0	0	2	5	2	0	0	0	0	0
6	0	0	0	25	157	236	212	106	5	0	0	0
7	0	1	114	272	355	512	461	384	261	82	3	0
8	23	60	304	510	482	662	647	619	577	297	59	27
9	181	424	491	723	704	911	952	852	781	519	337	242
10	441	567	693	899	869	1092	1161	1033	996	695	419	364
11	494	613	792	994	896	1140	1182	1129	1136	787	497	428
12	550	770	831	892	860	1050	1100	1035	1137	861	600	495
13	603	758	820	888	861	1021	1065	985	1112	860	594	469
14	719	725	830	841	853	1004	1003	953	1033	793	655	580
15	626	654	730	1028	3061	4267	4073	2465	942	691	535	495
16	389	510	2232	4506	5666	8219	7516	6323	4401	1734	383	313
17	391	783	4235	7362	6943	9810	9676	9244	8132	3829	600	376
18	1993	5007	5992	9035	7874	10486	11162	10351	9681	6056	3754	2626
19	4537	6107	7170	9106	8236	10255	11570	10211	9986	6932	4217	3609
20	4427	5706	6821	8487	7829	10220	10888	9882	9411	6385	4266	3612
21	3884	5154	5915	6322	6632	8742	9058	7910	8191	5714	3662	3033
22	3401	4567	5478	6419	6710	8454	8634	7600	8644	6371	4056	2751
23	5856	5689	7083	7410	7679	9018	9253	8615	9871	7264	6043	4840



Analysis Outputs (continued)

ANNUAL LOADS TABLE

MONTHLY AVERAGES (Wh)

vV^P

Inter-zonal Gains (Wh)

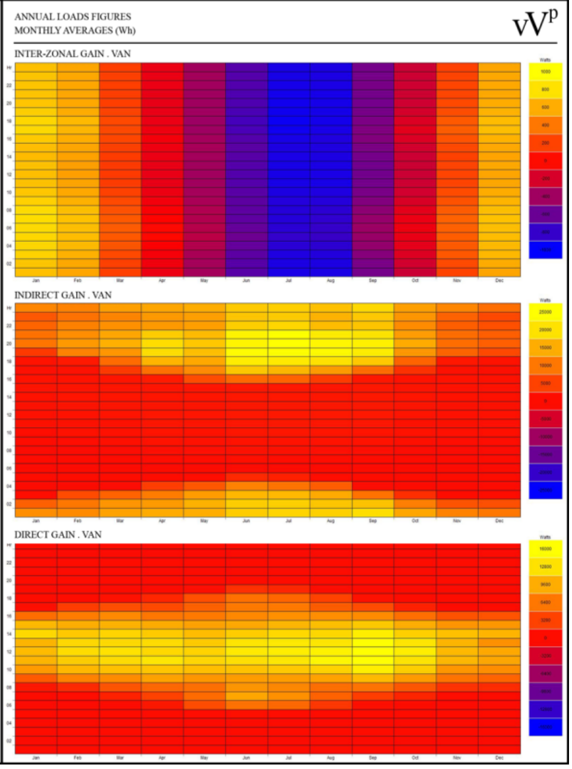
HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	671	573	189	-112	-387	-674	-906	-901	-561	-242	200	571
1	690	585	198	-100	-380	-669	-897	-891	-544	-217	231	598
2	739	614	226	-79	-366	-653	-882	-871	-503	-170	279	640
3	749	649	269	-44	-333	-624	-846	-831	-450	-139	291	650
4	759	660	282	-15	-300	-586	-807	-790	-430	-123	303	660
5	768	669	294	-12	-323	-621	-838	-800	-418	-109	315	669
6	776	676	288	-35	-338	-647	-856	-821	-441	-117	321	675
7	771	659	260	-58	-342	-644	-855	-833	-474	-146	297	660
8	734	614	229	-92	-362	-649	-868	-860	-514	-186	259	627
9	696	581	198	-114	-382	-666	-889	-885	-545	-218	234	596
10	676	564	180	-133	-397	-683	-908	-907	-566	-236	210	577
11	668	553	172	-128	-395	-687	-911	-906	-572	-245	203	571
12	671	553	175	-130	-393	-685	-910	-901	-572	-245	205	583
13	653	558	177	-122	-387	-675	-903	-894	-558	-235	198	567
14	667	572	192	-106	-378	-662	-890	-883	-538	-215	222	583
15	707	600	215	-85	-387	-686	-908	-880	-508	-179	263	622
16	760	635	225	-106	-407	-727	-939	-905	-519	-155	304	664
17	757	648	227	-120	-417	-744	-955	-925	-535	-178	286	656
18	725	598	204	-128	-400	-720	-942	-914	-555	-211	240	619
19	692	580	187	-132	-405	-705	-933	-916	-564	-229	225	595
20	684	578	184	-130	-404	-701	-927	-916	-562	-233	214	585
21	686	578	189	-118	-396	-690	-915	-903	-550	-229	211	584
22	688	581	193	-116	-391	-684	-909	-896	-552	-235	206	583
23	671	573	186	-119	-392	-682	-910	-898	-557	-241	194	569

Direct Solar Gains (Wh)

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	67	172	64	0	0	0	0	0
5	0	0	2	678	3816	6031	5541	2577	174	0	0	0
6	0	48	1215	3236	5655	9179	7899	5151	2915	1412	111	0
7	675	1780	4296	5407	5950	8180	7383	5816	6208	4389	2312	1913
8	4655	7013	7556	8948	8230	8600	8617	8941	10331	8514	6214	5231
9	8496	10200	10745	11099	10652	10857	11221	11824	13496	11550	8231	7687
10	10016	11450	12292	12953	12033	12564	13015	14016	15274	12840	10182	9260
11	10467	12421	12799	12188	11847	13229	13497	13720	15651	13508	10412	9335
12	10079	12161	12230	12328	11414	12909	13205	13002	15185	12982	10053	7863
13	12148	11246	11916	11340	10516	11451	12191	12105	13489	11652	10769	10025
14	10309	9694	9965	9462	8902	9368	10149	10603	11223	9607	8174	8358
15	5710	6681	7445	6332	6511	7383	7870	7744	7585	5821	4169	4249
16	148	2912	3925	3677	5036	6455	6448	4759	3790	1214	12	0
17	0	0	272	1531	4001	6040	5363	3193	263	0	0	0
18	0	0	0	0	169	2176	1573	90	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh)

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	12200	11707	14023	14841	15104	17867	18663	18250	19613	14490	11114	9906
1	7918	9955	12814	13307	15425	18010	18206	17286	16973	10753	6624	6210
2	78	5879	8107	10452	13392	15903	16253	14710	9495	3115	6	0
3	0	0	143	4615	6987	11009	9648	7579	187	0	0	0
4	0	0	0	0	89	2684	1860	47	0	0	0	0
5	0	0	0	0	2	5	2	0	0	0	0	0
6	0	0	0	24	153	228	207	103	5	0	0	0
7	0	1	111	264	342	495	446	372	253	79	3	0
8	22	55	293	492	461	636	623	598	560	287	54	25
9	173	412	472	694	674	875	916	820	753	501	327	235
10	427	547	665	864	831	1049	1116	993	957	668	403	351
11	475	588	757	952	854	1091	1132	1081	1090	754	475	410
12	525	737	792	851	817	999	1048	987	1086	822	573	473
13	576	723	781	844	818	970	1012	937	1059	821	566	447
14	687	692	791	799	829	1001	969	906	985	756	626	554
15	600	624	697	1342	5938	8500	8065	4448	945	659	512	475
16	372	500	4285	9354	11795	17441	15866	13273	9004	3407	398	301
17	557	1204	8876	15788	14606	20927	20623	19822	17568	8144	980	554
18	4146	10872	12885	19452	16652	22281	23854	22230	20965	13040	8058	5655
19	9773	13143	15302	19496	17398	21761	24687	21790	21362	14819	9003	7725
20	9534	12135	14397	17927	16353	21516	22963	20843	19918	13537	9074	7725
21	8201	10862	12374	13120	13680	18101	18824	16429	17156	11931	7638	6336
22	7065	9505	11317	13128	13658	17224	17677	15520	17527	12799	8132	5568
23	11347	11066	13804	14450	14985	17721	18178	16856	19042	13817	11382	9129



Analysis Outputs (continued)

ANNUAL LOADS TABLE
MONTHLY AVERAGES (Wh)
vP

Inter-zonal Gains (Wh) vP

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	677	583	232	-49	-312	-577	-784	-770	-435	-144	252	584
1	685	591	242	-38	-298	-561	-767	-754	-421	-132	261	592
2	695	602	254	-25	-284	-542	-748	-737	-404	-117	273	602
3	704	610	265	-14	-272	-527	-733	-723	-390	-104	284	611
4	712	617	273	-7	-265	-520	-724	-713	-379	-94	292	619
5	718	624	280	-4	-270	-530	-731	-713	-372	-85	300	626
6	724	629	276	-19	-286	-549	-748	-731	-388	-93	305	631
7	715	608	251	-43	-307	-574	-772	-755	-422	-125	277	613
8	680	573	218	-81	-337	-607	-807	-797	-469	-165	243	584
9	644	538	180	-127	-388	-671	-874	-854	-522	-211	211	553
10	613	509	136	-183	-436	-731	-937	-918	-587	-262	175	522
11	583	470	95	-216	-464	-768	-976	-960	-643	-311	132	491
12	552	437	68	-237	-483	-786	-999	-980	-678	-346	101	473
13	516	421	47	-248	-498	-795	-1012	-993	-692	-363	75	439
14	506	420	44	-246	-499	-794	-1009	-996	-688	-363	71	429
15	536	435	58	-227	-487	-783	-998	-982	-663	-339	99	456
16	586	465	85	-206	-477	-773	-986	-960	-631	-302	138	497
17	587	489	111	-186	-464	-757	-971	-942	-600	-284	142	499
18	591	496	122	-170	-443	-734	-947	-922	-586	-273	151	504
19	605	508	134	-154	-428	-716	-928	-904	-567	-252	172	521
20	632	526	155	-136	-411	-695	-907	-883	-535	-220	199	544
21	642	548	183	-110	-386	-669	-877	-852	-499	-196	211	553
22	653	559	198	-87	-356	-632	-841	-818	-476	-179	223	562
23	664	569	213	-71	-336	-603	-812	-795	-454	-161	236	572

Direct Solar Gains (Wh) vP

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	123	318	119	0	0	0	0	0
5	0	0	3	986	3141	4978	3855	1892	321	0	0	0
6	0	88	2006	5628	7858	9827	8608	7125	5078	1959	205	0
7	1682	4086	7292	10662	12511	14708	14159	12666	10873	7207	4114	2358
8	6465	9496	12617	17410	17693	20438	20390	18902	18275	12935	8074	6518
9	11169	14800	18388	21140	22389	24587	25541	24018	24029	18098	11796	10251
10	13762	17483	21269	24579	24832	27877	28868	27938	27396	20674	15102	12777
11	14959	19500	22363	23218	24398	28931	29188	27367	28349	22210	15916	13471
12	14507	19346	21539	23683	23831	28234	28777	26268	27670	21265	15080	11480
13	17075	17761	20793	21780	22185	25378	26503	24456	24417	18948	15624	13680
14	13492	14803	17295	18245	19159	21470	22729	21946	20443	15110	10973	9979
15	7251	9794	12772	12654	14953	17532	18366	16760	13936	9079	5267	4762
16	274	4003	6896	7742	10210	12800	13042	10870	7118	1897	23	0
17	0	0	503	2489	5188	7494	7227	4701	479	0	0	0
18	0	0	0	0	312	1620	1297	165	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

Indirect Solar Gains (Wh) vP

HOUR	JAN	FEB	MAF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	22	1209	1134	796	616	782	781	750	989	429	2	0
1	0	0	41	228	817	1357	1111	532	40	0	0	0
2	0	0	0	0	26	614	429	14	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	19	49	18	0	0	0	0	0
5	0	0	0	262	1733	2465	2341	1221	49	0	0	0
6	0	14	1215	2692	3259	4786	4333	3670	2592	1272	32	0
7	809	1850	2871	4435	4497	6283	5943	5525	4815	2816	1667	1280
8	2325	3297	4062	5942	5423	6915	7254	6890	6451	4113	2553	2118
9	3163	4347	5125	6777	7178	9239	9638	8291	7337	4968	3114	2811
10	3616	4673	6105	8070	8060	10303	10751	9529	8601	5875	3538	2962
11	3774	5344	6507	7952	7643	9934	10230	9368	8840	6091	4208	3477
12	4235	5608	6366	7434	7362	9099	9352	8567	9179	6850	4582	3649
13	5267	6231	7175	7966	8997	11126	11595	9713	9779	7404	5348	4396
14	6106	6261	7661	8429	9157	11531	11486	10235	10298	7644	5716	4979
15	5504	6744	8015	8005	8278	10084	10113	9530	10390	7735	5588	4925
16	3745	6554	7275	8039	8130	8966	9196	9337	9309	6218	3997	3571
17	4706	5538	5504	6982	7201	8322	8451	8270	6782	5779	4374	4162
18	5463	5536	5228	5478	4748	6155	6084	5978	6658	6093	5147	4973
19	5411	5755	5384	4667	4084	4638	4870	5192	6868	6200	4817	4535
20	4307	5260	4921	4524	3971	4497	4714	4892	6232	5239	4004	3092
21	5360	4194	3969	3684	3332	3848	3915	4072	4634	4284	4486	4353
22	4861	3731	3273	2563	1823	2172	2297	2588	3724	3698	3691	4111
23	2547	2641	2419	1650	1101	930	1244	1658	2443	2165	1877	2125