DETERMINATION OF ENERGY EFFICIENT CONSTRUCTION COMPONENTS FOR HOUSES IN NORTHERN CYPRUS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF APPLIED SCIENCES
OF
NEAR EAST UNIVERSITY

by

KHALED AHMAD SHANABLIH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE
IN MECHANICAL ENGINEERING

Nicosia 2012

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DECLARATION

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

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Date: 23-04-2012

ABSTRACT

Being the main source of energy, fossil fuels are one of the main causes of global warming. The reserves are also decreasing every day. Nowadays, effective usage of alternative energy resources is a major aim. Decreasing the energy usage became a critical aspect. Energy loss in space heating applications has high percentage over wasted energy. The aim of this study is to investigate the situation of houses in Northern Cyprus in this extent, to estimate and the amount of energy used for space heating compare with European standards and countries, to determine required insulations for houses according to European standards and to estimate the amount of energy that will be saved if all the houses are constructed accordingly.

For this purpose, a questionnaire was conducted among 231 participants and 67 architectural plans were examined to investigate the situation of houses and the main source and way of energy usage for space heating and cooling applications. The results of the questionnaire were compared with national population and house census in 2006 of TRNC-Pry Ministry Governmental Office of Planning for verification. It was determined that more attention must be taken for insulation of houses since the results of questionnaire showed that 94% of houses have no insulation on walls and 89% on roofs.

Energy losses through walls and roofs per square meter per year were calculated to be 103 MJ/m^2 year and 57 MJ/m^2 year, respectively, in Northern Cyprus. These values are 98 % and 63 % more than European recommended values of 52 MJ/m^2 year and 35 MJ/m^2 year, respectively. Total energy loss per year for North Cyprus was estimated to be 5305 MJ/year which is only 0.1 % of the European total. It was determined that 3 cm and 7 cm of polystyrene or glass wool insulation for terracotta brick walls and concrete roofs, respectively, and double glazed windows will be enough to reduce the heat losses to European standards and will reduce the total energy loss per year by about 50 %. If concrete blocks are used instead of terracotta bricks no additional insulation material will be required.

ACKNOWLEDGEMENT

I am heartily thankful to my **Assist. Prof. Dr. Ali Evcil**, **Assist. Prof. Dr. Cemal Govsa, Assist. Dr. Lida**, and **Assist. Prof. Dr. Tayseer Al Shanableh** whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject.

Lastly, I offer my regards and blessings to my **family** and **parents** who supported me in any respect during the completion of the project.

Khalid A. Shanablih

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INTRODUCTION

Energy from the sun drives the earth's weather and climate, and heats the earth's surface; in turn, the earth radiates energy back into space. Atmospheric greenhouse gases (water vapor, carbon dioxide, and other gases) trap some of the outgoing energy, retaining heat some what like the glass panels of a greenhouse.

Without this natural "greenhouse effect," temperatures would be much lower than they are now, and life as known today would not be possible. The earth's average temperature is a more hospitable 15 °C. However, problems may arise when the atmospheric concentration of greenhouse gases increases.

Since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide is increasing, methane concentrations as well. These increases have enhanced the heat-trapping capability of the earth's atmosphere. Scientists generally believe that the combustion of fossil fuels and other human activities are the primary reason for the increased concentration of carbon dioxide. Plant respiration and the decomposition of organic matter release more than 10 times the CO_2 released by human activities; but these releases have generally been in balance during the centuries leading up to the industrial revolution with carbon dioxide absorbed by terrestrial vegetation and the oceans.

How much the burning of fossil fuels is increasing global warming, is still a matter of debate among scientists. Fossil fuels are the main source of energy on earth and the reserves are decreasing every day. Being the main source of energy, fossil fuels are also one of the main causes of carbon dioxide emission to the atmosphere, increasing the greenhouse effect resulting in global warming which is one of the most important threats on earth. People are trying to find ways for effective usage of alternative energy resources which are clean and will exist as long as the earth exists. It is important to decrease the energy usage to extent the time period for fossil fuels and to decrease the global warming. One of the most important things to decrease the energy usage is to insulate the buildings for air infiltration and heat transfer.

Almost all of the houses in North Cyprus are not well constructed from the environment point of view. Enormous amounts of energy are needlessly wasted in both summer and winter, through cheap and simple construction. Insulating in North Cyprus is poor; most of houses in North Cyprus are not insulated at all.

The aim of this study is to investigate the situation of houses in North Cyprus, to estimate and compare the amount of energy used for space heating with European standards and countries, to determine required insulations for houses according to European standards and to estimate the amount of energy that will be saved if all the houses are constructed accordingly.

Chapter one is an introduction to insulation, giving benefits and properties of insulation, and the relation between insulation and heat transfer. In Chapter two the insulation materials for building and all kind of suitable insulation materials are described. Chapter three describes the insulation applications in buildings during the construction which is an easier and more efficient way to reduce the energy loss than existing buildings. In chapter four climate classification and the effect of global warming are presented in general, concluding the situation of North Cyprus as the main area of interest. In Chapter five the European Standards for insulation and the EURIMA studies of insulation in walls and roofs with their thickness, and the energy losses through them per country are presented.

In the last chapter, the results of a questionnaire conducted among 231 participants and 67 architectural plans examined to investigate the situation of houses in North Cyprus were presented. Total heat transfer coefficients of building components, total energy loss per year, and energy loss through walls and roofs of houses were calculated. The required level of insulation for North Cyprus were calculated and presented to reach the standards of European Countries.

1. THERMAL INSULATION

1.1 Introduction

Global warming is gaining the attention of the media and scientists worldwide. The building industry, including how we power these buildings, how we live in them, and what we put in them, has played a significant role in global warming [1]. Better architecture and energy savings in buildings could do more to fight global warming on greenhouse gases agreed under the U.N.'s Kyoto Protocol [2].
Better use of concrete, metals and timber in construction and less use of energy for everything from air conditioners to lighting in homes and offices could save billions of dollars in a sector accounting for 30-40 percent of world energy use.

"Buildings can play a key role in combating climate change," the U.N. Environment Programme said in a report issued in Oslo during a conference on ways to promote economic growth without damaging the environment.
Simple measures include more blinds to keep out the sun in hot climates, switching to energy efficient light bulbs, better insulation and ventilation. "Avoid building a bigger house than you need".
Without this natural “greenhouse effect,” temperatures would be much lower than they are now, and life as known today would not be possible. The earth’s average temperature is a more hospitable 16 °C. However, problems may arise when the atmospheric concentration of greenhouse gases increases [1].
Since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%. These increases have enhanced the heat-trapping capability of the earth’s atmosphere [1].
Scientists generally believe that the combustion of fossil fuels and other human activities are the primary reason for the increased concentration of carbon dioxide. Plant respiration and the decomposition of organic matter release more than 10 times the CO_2 released by human activities; but these releases have generally been in balance during

the centuries leading up to the industrial revolution with carbon dioxide absorbed by terrestrial vegetation and the oceans [1].

Making new buildings more energy efficient will cut fuel use and costs, but for big savings we need to retrofit the enormous stock of older buildings by replacing old refrigerators, switching to high efficiency lights, tuning up boilers, and installing solar water heaters can lead to significant energy savings [3].

Right now, solar and wind provide only a tiny fraction of our electricity needs. Lots of small solar electric and thermal power systems on top of houses and buildings and larger solar and wind systems in rural areas can take pressure off our overstretched electric grid [3].

Over the past 30 years, rising energy costs and energy conservation concerns have required that the building industry improve the thermal efficiency of new construction. So insulation is designed to offer thermal benefits as well, which can reduce energy costs [3]

The insulation is necessary for energy efficient building envelope construction, considering the environment, the health, safety and quality of living while saving money and energy at the same time. All these objectives can be easily achieved by insulating the building, which makes the building more comfortable by maintaining a more uniform temperature throughout the year. It is also effective in term of undesired noise [4]. The only way to maximize your home's energy efficiency is to insulate all the areas of your home susceptible to air infiltration and heat transfer [5].

Thermal insulation is applied in a building for several reasons. All of these relate to the primary characteristics of a thermal insulating material; it provides relatively good resistance to the flow of heat. The reduction of heat loss in winter provides savings in heating costs and the reduction of heat gain in summer will reduce the cost of cooling where summer air-conditioning is provided. Insulation in walls, ceilings and sometimes floors is also desirable in all buildings intended for human use because comfort conditions are more easily achieved. For buildings in which moderate to high relative humidities are to be maintained in winter, insulation is necessary to prevent surface condensation on walls, ceilings and floors [5].

With few exceptions the basic constructions employed in houses do not of themselves provide sufficient insulating value. It is necessary or desirable in most cases to add a layer of insulation to improve the over-all resistance to heat flow. Ideally it would be best if this insulating layer could be applied to the building. In this way the insulation would be continuous over the building and its structure would be protected from the extremes of temperature both winter and summer [5].

1.2 Properties of Insulation

The properties of Insulation materials must be considered carefully during design or application, generally significant properties are given in the manufacturing catalogues, any properties which may be significant for certain application and not given by manufacturer must be tested and determined.

The following properties are referenced only according to their significance in meeting design criteria of specific applications [6].

1.2.1 Thermal Properties of Insulation

Thermal properties are the primary consideration in choosing insulations [6].

- **Temperature limits:** Upper & lower temperatures within which the material must retain all its properties.
- **Thermal conductance "C":** The rate of heat flow for the actual thickness of a material.
- **Thermal conductivity "K":** The rate of heat flow for unit thickness of a material.
- **Emissivity "ε ":** It is a measure of a material's ability to absorb and radiate energy; emissivity is a numerical value and does not have units [7].
- **Thermal resistance "R":** R-value is a measurement of a material's resistance to heat flow. Insulation materials have tiny pockets of trapped air that resist the transfer of heat through the material. (The code assumes that insulation is installed properly and is not compressed in any way.) The ability of insulation to

slow the transfer of heat is measured in R-values. The higher the R-value, the better the insulation material's ability to resist the flow of heat through it.

- **Thermal transmittance "U":** The overall conductance of heat flow through a "system".

1.2.2. Mechanical and Chemical Properties of Insulation

Properties other than thermal must be considered when choosing materials for specific applications [6].

- **Alkalinity (pH or acidity)**: Alkalinity is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH. The presence of buffering materials helps neutralize acids as they are added to the water [8].
- **Appearance:** Important in exposed areas and for coding purposes [6].
- **Breaking load:** load which causes fracture in a tensile, compression, flexure or torsion test. In tensile tests of textiles and yarns, breaking load also is called breaking strength. In tensile tests of thin sheet materials or materials in form of small diameter wire it is difficult to distinguish between breaking load and the maximum load developed, so the latter is considered the breaking load. Breaking Strength Tensile load or force required to rupture textiles (eg, fibers, yarn) or leather [9].
- **Capillarity:** Must be considered when material may be in contact with liquids [6].
- **Chemical reaction:** Potential fire hazards exist in areas where volatile chemicals are present. Corrosion resistance must also be considered [6].
- **Chemical resistance**: Significant when the surrounding matter is salt or chemical laden [6].

- **Coefficient of expansion and contraction:** Enters into the design and spacing of expansion/contraction joints and/or the use of multiple layer insulation applications [6].
- **Combustibility:** One of the measures of a material's contribution to a fire hazard [6].
- **Compressive strength:** Important if the insulation must support a load or withstand mechanical abuse without crushing. If, however, cushioning or filling in space is needed as in expansion/contraction joints, low compressive strength materials are specified [6].
- **Density:** A material's density affects other properties of that material, especially thermal properties.
- **Dimensional stability:** Significant when the material is exposed to atmospheric and mechanical abuse such as twisting or vibration from thermally expanding pipe.
- **Fire retardancy:** Flame spread and smoke developed ratings should be considered.
- **Hygroscopic**: is the capacity of a product (e.g. cargo, packaging material) to react to the moisture content of the air by absorbing or releasing water vapor. Of decisive significance for the absorption or release of water vapor is the water content of a product.
- **Resistance to ultraviolet light:** Significant if application is outdoors.
- **Resistance to fungal or bacterial growth:** Is necessary in food or cosmetic process areas.
- **Shrinkage:** Significant on applications involving cements and mastics.
- **Sound absorption coefficient:** Must be considered when sound attenuation is required, as it is in radio stations, some hospital areas, etc.
- **Sound transmission loss value:** Significant when constructing a sound barrier.
- **Toxicity:** Must be considered in food processing plants and potential fire hazard areas [6].

1.3 Importance of Insulation

Figure 1.1 shows the infrared pictures of non-insulated and insulated house for compassion.

Heating and cooling account for 50 to 70% of the energy used in the average homes. About 20% goes for heating water. On the other hand, lighting and appliances and everything else account for only 10 to 30% of the energy used in most residences. It makes good sense to turn lights and appliances off when they are not needed, and you'll save even more on your energy costs if the reduce the amount of energy needed for heating and cooling [10].

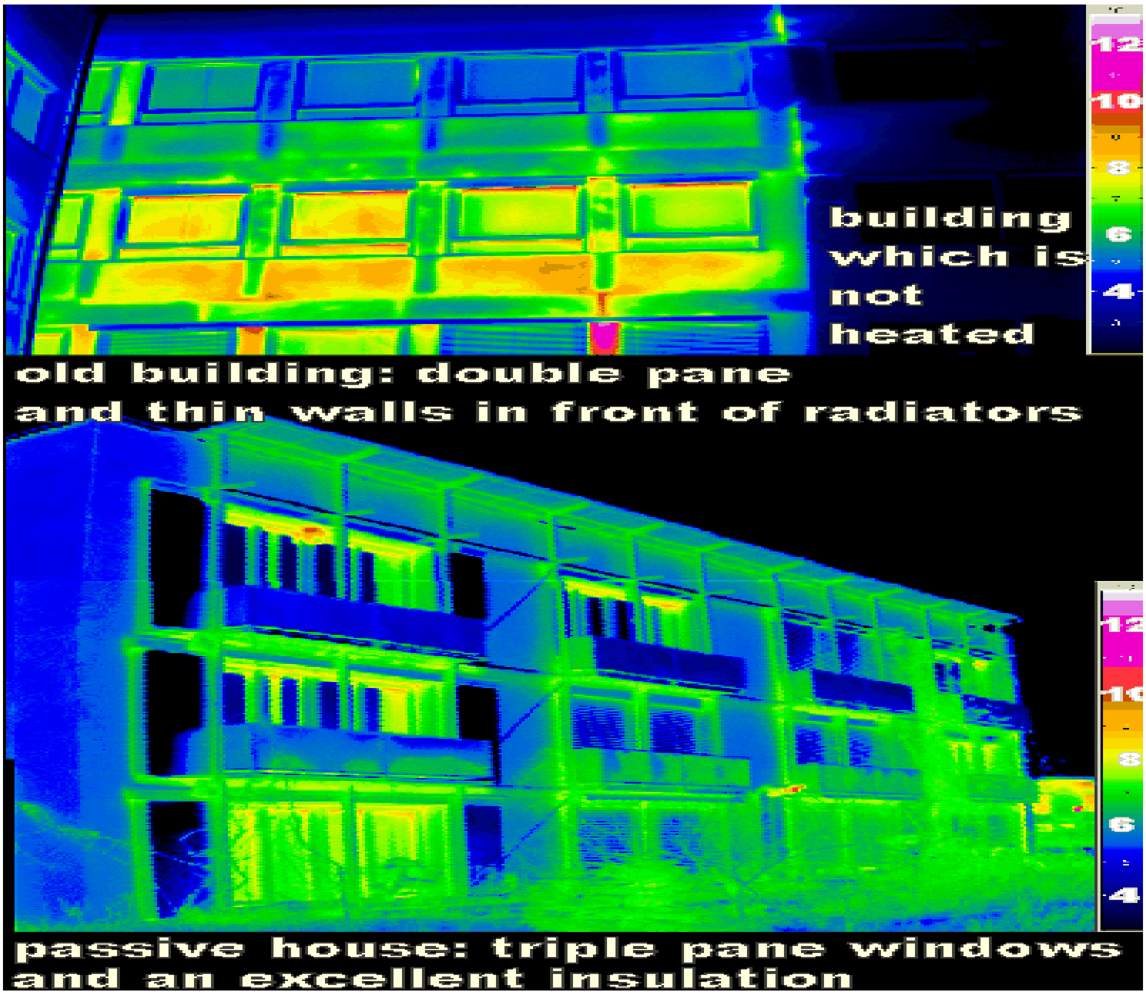


Figure 1.1: Infrared Pictures of an Old Building and a Passive House (at the bottom) for Comparison [11].

Unless your home was constructed with special attention to energy efficiency, adding insulation will probably reduce your energy consumption. Much of the existing housing stock in the world is not insulated to the best level. Older homes are likely to use more energy than newer homes, leading to very high heating and air-conditioning load. Even if you own a new home, adding insulation may save enough money in reduced utility bills to pay for itself within a few years [10].

It should be stated that insulation of buildings are of prime importance, the level of energy consumption and utility bills are considered, insulation will also decrease Carbon dioxide (emission), the main cause of global warming which has become a thread for our world in recent years.

It is most important to:

- Insulate your attic to the recommended level, including the attic door, or hatch cover.
- The recommended level of insulation must be provided under floors above unheated spaces, around walls in a heated basement or unventilated crawl space, and on the edges of slabs-on-grade.
- Exterior walls of a building must be insulated at recommended levels [10].

1.4 Heat Transfer and Insulation

Heat always moves from a warmer area to a colder area. During the winter, heat is transferred from the interior of a heated building to the exterior. In the summer, heat can be transferred from the exterior to the interior during the day and may move in the other direction at night when it is cooler outside [1].

Heat is transferred by three mechanisms; conduction, convection and radiation.

1.4.1 Conduction

Conduction occurs in a material when the molecules are excited by a heat source on one side of the material. These molecules transmit energy (heat) to the cold side of the material. Conduction occurs primarily through the foundation and framing members in buildings [2]. Poor conductors of heat are placed between materials as insulators.

1.4.2 Convection

Convection is transfer of heat when a fluid is in motion. Since air and water do not readily conduct heat, they often transfer heat through their motion. A fan-driven furnace is an example of this [12].

1.4.3 Radiation

Hot and even warm objects radiate infra-red electromagnetic waves, which can heat up objects at a distance, as well as lose energy themselves. Insulation against heat transfer by radiation is usually done by using reflective materials [12]

1.5 Applicable of Insulation

Figure 1.2 shows which building spaces should be insulated [1].

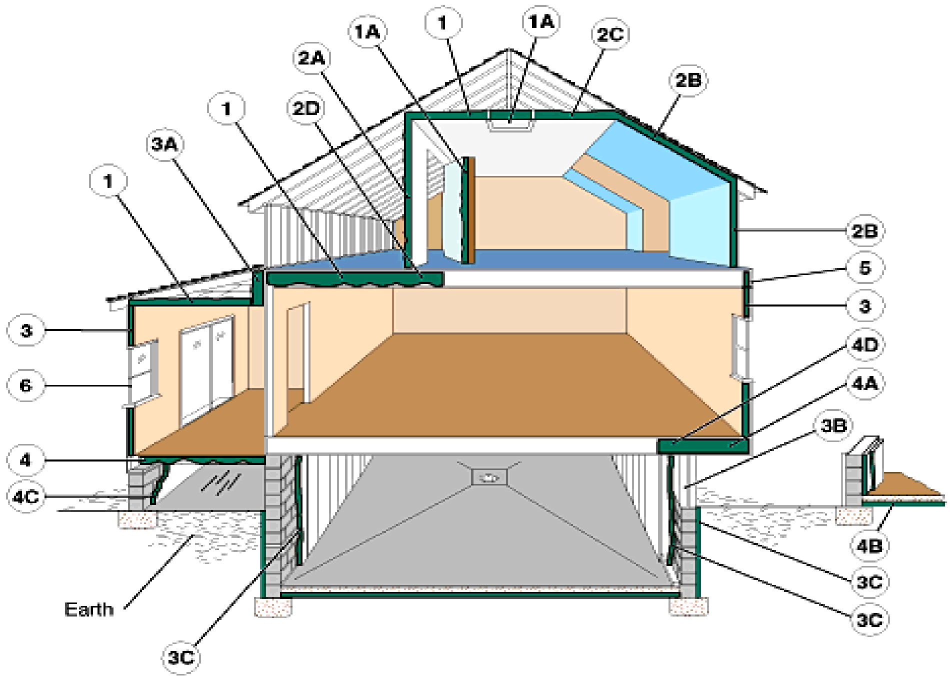


Figure 1.2: Places in a Typical House Where Insulation Should be Installed.

1. In unfinished attic spaces, insulate between and over the floor joists to seal off living spaces below.*1A attic access door.

In finished attic rooms with or without dormer, insulate

2A between the studs of "knee" walls;

2B between the studs and rafters of exterior walls and roof;

2C ceilings with cold spaces above;

2D extends insulation into joist space to reduce air flows.

2. All exterior walls, including

   3A walls between living spaces and unheated garages, shed roofs, or storage areas;

   3B foundation walls above ground level; 3C foundation walls in heated basements, full wall either interior or exterior.

3. Floors above cold spaces, such as vented craw spaces and unheated garages. Also insulate ...

   4A any portion of the floor in a room that is cantilevered beyond the exterior wall below;

   4B slab floors built directly on the ground;**

   4C as an alternative to floor insulation, foundation walls of unvented crawl spaces;

   4D extend insulation into joist space to reduce air flows. .

4. Band joists.
5. Replacement or storm windows and caulk and seal around all windows and doors.

*Well-insulated attics, crawl spaces, storage areas, and other enclosed cavities should be ventilated to prevent excess moisture build-up.

**For new construction, slab on grade insulation should be installed to the extent required by building codes, or greater [11].

1.6 Some Design Options for Building Insulation

Some new homes are built using metal frames instead of wood. When you insulate a metal-framed building, it is important to recognize that much more heat flows through metal studs and joists than through pieces of wood. Because of this difference, placing insulation between the wall studs, or between attic or floor joists, doesn't work as well for metal-framed houses as

it does for wood-framed houses. If your walls have metal frames, you will probably need to place continuous insulative sheathing over the outside of the wall frame, between the metal framing pieces and your exterior siding. (Note that this insulative sheathing cannot take the place of plywood or other seismic bracing.) If your attic has metal joists, you may want to place rigid foam insulation between the joists and the ceiling drywall. It's important to recognize that even if you install the recommended level of insulation in a metal frame building, you will not necessarily get thermal performance as good as you would get from a wood structure with its recommended level.

Insulating concrete forms can be used to construct walls for new homes. These special concrete walls come in a variety of configurations and can provide additional thermal mass to your home to help reduce the effect of outdoor temperature swings.

Structural insulated panels can also be used to construct a house. These panels sandwich plastic foam insulation between two layers of a wood product, thus eliminating the need for structural wood framing members. This system can reduce air leaks into and out of the structure and therefore may offer improved thermal performance compared to stick-built walls.

Some homes are built with an External Insulation Finish System (EIFS) that gives a stucco-like appearance. There is some controversy right now about whether or not these homes are likely to experience moisture problems [10].

1.7 Infiltration of Air

The air enters the living space from other unheated parts of the house and from outside uncontrolled infiltration air must be heated or cooled causing energy loss and must be prevented. Chimneys, door and window frames are the main source of infiltration for concrete buildings. Chimneys of fire place must be closed when not in use. The joints of door and window frames must be insulated by rubber strips to prevent infiltration of air [10].

1.8 Ventilation

Although uncontrolled infiltration of air is unwanted adequate ventilation in a house is important for two reasons:

- Moisture Control - Ventilation will prevent elevated moisture levels within the conditioned space during the heating season. These elevated levels can lead to condensation on window surfaces and give rise to surface mold and mildew, as well as concealed condensation within walls and roof spaces [10].

- Avoiding Indoor Air Pollution - When natural ventilation has been sharply reduced, as in super-energy-efficient houses, it may be necessary to provide fresh air ventilation to avoid build-up of stale air and indoor air pollutants. Special air exchange units with heat-saving features are available for this purpose.[10]

When the attic or crawlspace is properly ventilated, a positive air flow is created which allows the house to breathe and helps prevent moisture build-up [10].

In hot weather, proper ventilation prevents the attic from becoming a hot box. In cold weather, proper ventilation helps to prevent moisture from condensing on the insulation, building structure and the underside of the roof deck [10].

1.9 Thermal Insulation of Passive Houses

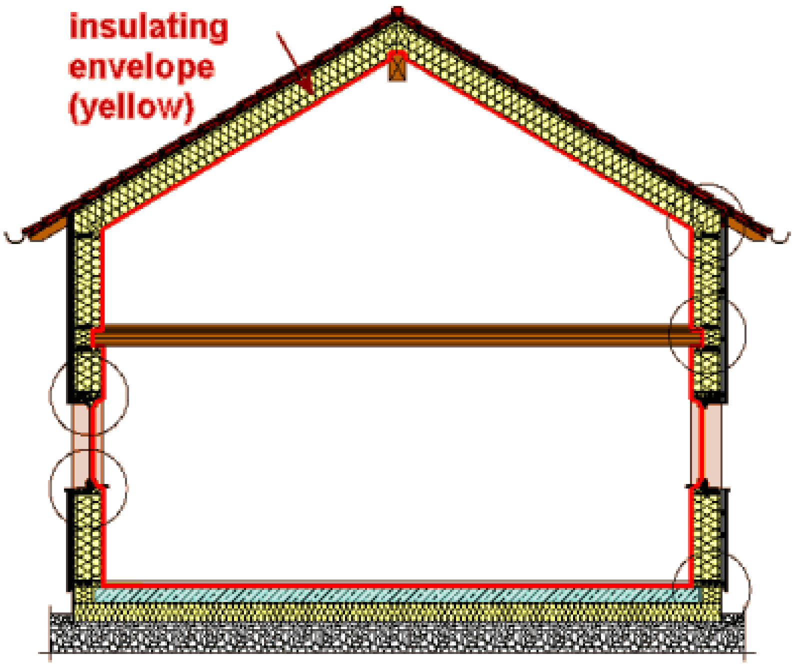


Figure 1.3: Insulation Applicable.

Passive houses are working examples of dwellings (houses) with very good thermal insulation standards.

A key feature of a passive house is that they incorporate very high standards of insulation. This reduces the amount of heat lost through the building fabric to a very low level. When achieving these very high standards of insulation the purpose provided heating requirement, even on the coldest days, is reduced to a minimum and hence it is possible to adequately heat the dwelling by just preheating the fresh air entering the rooms.

The heat loss through a regular construction (an external wall, a floor to the basement or a slab on ground, a ceiling or a roof) is characterized by the thermal heat loss coefficient or U-value. This value shows how much heat (in Watts) is lost per m^2 at a standard temperature difference of 1 degree Kelvin. The international unit of the U-value therefore is W/(m²K). The heat loss of a wall can be calculated by multiplying the U-value by the area and the temperature difference [11].

The following table presents the typical heat losses for different external walls based on a typical European single family house with an external wall area of 100 m². Winter temperatures of -12 °C outside and 21 °C at the inside are used as they are typical of Central Europe.

Table 1.1: Typical Heat Losses for Different External Walls.

U-Value	Heat Loss (Load)	Annual Heat Loss	Annual Costs (2005) only of the heat loss of external walls
W/m²K	W	kWh/(m²a)	€/a
1.00	3300	78	429.-
0.80	2640	62	343.-
0.60	1980	47	257.-
0.40	1320	31	172.-
0.20	660	16	86.-
0.15	495	12	64.-
0.10	330	8	43.-

Examples of constructions suitable for passive houses with an excellent thermal insulation: Masonry construction with thermal insulation compound system, timber construction, lost forms of insulation.

A typical compact services unit for a passive house will typically deliver ~1000 W without a problem. For the compact service unit to meet the total heat loss (floor, windows, doors, roof in addition to the external walls) the K-value of the wall has to be really low, suitable are values in the range between 0.1 to 0.15 W/(m²K). This means that the heating requirement matches the output of the compact services unit. It is obvious that K-values that low only can be achieved using really good insulating materials [11].

2. INSULATION MATERIALS FOR BUILDINGS

As we discussed in the first chapter insulation materials can be used to reduce the rate of heat transfer through external surfaces of buildings. Heat always flows from high temperature to low temperature. It limits heat from escaping from a building in winter, and unwanted heat coming into a building in summer. In temperature controlled buildings, this will result in significant energy savings and thermal comfort. The amount of heat loss in winter and heat gain in summer should be reduced by installing the correct level of insulation. Insulation has a second benefit it reduces noise transfer through walls and ceilings.

Some of the main reasons for insulating a building can be summarized as follows:

- Insulation, correctly installed, allows the building to stay considerably warmer in winter and cooler in summer, making it much more comfortable to live in.
- It is an important element of an energy efficient house design.
- It will save money on your heating and cooling bills.
- It helps the environment by reducing the amount of energy required to heat and cool the building and therefore less greenhouse gas will be emitted.

Insulation consists of a variety of materials and comes in many forms. These include fibrous insulation, foam insulation, insulated panels, straw panels, and insulating masonry products, as well as specialized devices to aid proper insulation techniques. Alternatives to conventional fiberglass, cellulose, and mineral wool are constantly being explored [10].

The following describes the insulation types and the most of the available insulation forms, insulation materials, their installation methods, their application areas, and their advantages.

2.1 Blanket Batts and Rolls Form

Blankets as it is shown in Figure 2.1 are flexible products made from mineral fibers. They are available in widths suited to standard spacing of wall studs and attic or floor joists. Continuous rolls can be hand-cut and trimmed to fit. They are available with or without vapor retarder facings. Batts with a special flame-resistant facing are available in various widths for places where the insulation will be left exposed, such as basement walls.

The application areas of blankets include unfinished walls, walls, floors and ceilings. The advantages of blankets are they suit for standard stud and joist spacing, which is relatively free from obstructions, and easy to apply [13].

Figure 2.1: Blanket Insulation Materials.

For blankets the following materials are used;

- Fiberglass
- Mineral wool
- Plastic fibers
- Natural fibers

Fiberglass

Manufacturers now produce medium and high density fiberglass batt insulation with higher R-values than existing low density batts. These new products are appropriate for insulating building envelopes with limited cavity space (for example, cathedral ceilings). Medium density batts have twice the fiberglass as the low density batts, and the high density batts have three times as much [14].

Figure 2.2 Fiber Glass.

Mineral Wool

Mineral wool as it is shown in Figure 2.3 refers to three types of insulation made from raw materials spun into loose fill or batt products:

- "glass wool," or "fiberglass," made from recycled glass or silicates
- "rock wool," made from virgin basalt and igneous rock
- "Slag wool," made from steel-mill slag.

Most of the "mineral wool" is actually "slag wool". Most U.S. made mineral wool is stiff and brittle. Mineral wool insulation is fire resistant and aids sound-proofing.

A softer, mineral wool batt product is also available. The edge of this new Canadian-made batt is highly compressible. This allows insertion of the batt between framing members. It then expands to continuously press against both framing members. The result is a friction-fit installation that increases the overall insulation effectiveness [14].

Figure 2.3: Mineral Wool.

Plastic Fiber Insulation

Plastic fiber batts are made from recycled polyethylene terephthalate (PET) commonly used to make milk containers. The fibers are thick, making extremely soft batt insulation that looks like high-density fiberglass.

The recycled content and clean manufacturing process help make this insulation a good addition to the market. The insulation also does not irritate the skin. It does not burn when exposed to an open flame, but it melts at a low temperature (a definite disadvantage). The batts are also difficult to cut with standard job and needs site tools [14].

Natural Fibers

Several natural fibers are being analyzed for their potential insulating properties. The most notable of these include cotton, wool and straw.

Cotton thermal insulation is no longer produced, Cotton based insulation consists of recycled cotton and plastic fibers. Cotton insulation has similar thermal properties as fiberglass and cellulose insulation. Some chemically sensitive consumers feel that this type of insulation is healthier to use than other types.

Wool and hemp insulation are relatively unknown in developed countries, but have been in use in other, less industrialized countries. Both products offer similar R-values to other fibrous insulation types [15].

2.2 Concrete Block Insulation

Insulated concrete blocks take on many different shapes and compositions. The better concrete masonry units reduce the area of connecting webs as much as possible. The cores are filled with insulation-poured-in, blown-in, or foamed-in-except for those cells requiring structural steel reinforcing and concrete infill. This raises the average wall R-value.

Some block makers coat polystyrene beads with a thin film of concrete. The concrete serves to bond the polystyrene while providing limited structural integrity. Expanded polystyrene mixed with Portland cement, sand, and chemical additives are the most common group of ingredients.

For concrete block insulation, the application areas are unfinished walls, including foundation walls, for new construction or major renovations. [13].

The following insulation materials are used for concrete block insulation:

- Polystyrene
- Polyisocyanurate or polyiso
- Polyurethane

Polystyrene

Polystyrene is commonly used to make foam board or beadboard insulation, concrete block insulation, and a type of loose-fill insulation, which consists of small beads of polystyrene.

Molded expanded polystyrene (MEPS) more commonly used for foam board insulation is also available as small beads of foam. This type is often used as a pouring insulation for concrete blocks or other hollow wall cavities. However, poured beads are extremely lightweight and take a static electric charge very easily. Any wind at all often results in the beads flying all over the place. Also, if there is a hole in the wall, the foam beads will continue to fall out of the hole [14].

Polyisocyanurate or polyiso

Polyisocyanurate or polyiso is a thermosetting type of plastic, closed-cell foam that contains a low-conductivity gas (usually hydrochlorofluorocarbons or HCFC) in its cells. Polyisocyanurate insulation is available as a liquid, sprayed foam, and rigid foam board. It can also be made into laminated insulation panels with a variety of facings. Foamed-in-place applications of polyisocyanurate insulation are usually cheaper than installing foam boards. They also usually perform better since the liquid foam molds itself to all of the surfaces.

Over time, the R-value of polyisocyanurate insulation can drop as some of the low-conductivity gas escapes and air replaces it [14].

Polyurethane

All closed-cell polyurethane foam insulation made today is produced with a non-CFC (chlorofluorocarbon) gas as the blowing agent. This gas doesn't insulate as well as insulation made with a CFC gas, however it is less destructive to our planet's ozone layer. Their density is generally 32.0 kg/m^3 (2.0 lb/ft^3). There are also low-density open-cell polyurethane foams 8 kg/m^3 (0.5 lb/ft^3). These are similar to conventional polyurethane foams, but are more flexible. Some low-density varieties use carbon dioxide (CO_2) as the blowing agent.

Low-density foams are sprayed into open wall cavities and rapidly expand to seal and fill the cavity. Slow expanding foams are also produced. Types intended for cavities in existing construction where there is no insulation. The liquid foam expands very slowly and thus reduces the chance of damaging the wall from over-expanding. The foam is water vapor permeable, remains flexible [14].

2.3 Reflective System

Reflective insulation works by letting through only a small percentage of the radiant heat it receives and reflecting the rest using a shiny surface. A gap next to the reflective surface creates a still layer of air, which is important for reducing heat flow. Reflective insulation comes as flexible metallic foils with either one or both sides reflective, as single or multiple layers. It should be perforated to improve movement of moisture away from surfaces. Most reflective systems range from one to five enclosed air spaces [16], as shown in the Figure 2.4 and Figure 2.5.

Figure 2.4: Reflective System**.**

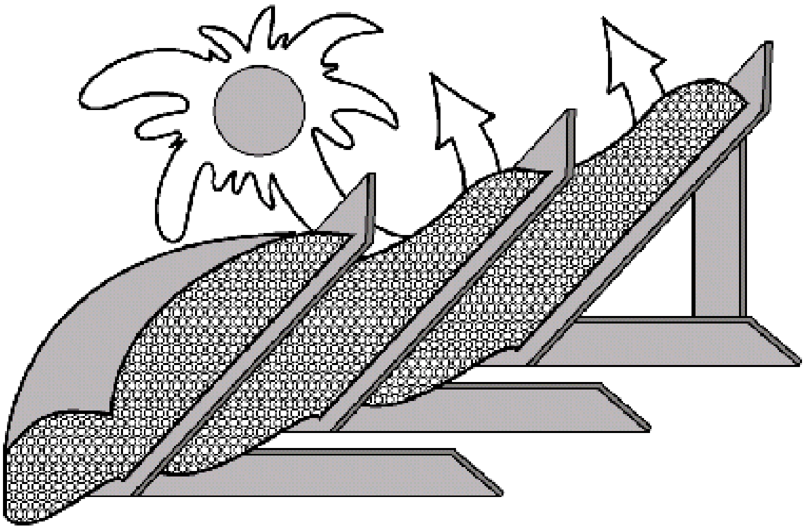


Figure 2.5: Schematic Representation of Reflective Insulation Installed Between Framing Members.

There are other beneficial considerations for using reflective insulation. Generally, these products have a very low water vapor and air permeance. When installed properly, with joints taped securely, reflective insulation materials are efficient vapor retarders and an effective barrier to air and gas.

Since reflective insulation materials are effective vapor retarders, care should be taken to ensure that they are installed correctly within the structure. Correct installation depends on the climatic conditions and moisture sources involved. An appropriate installation ensures that all joints and seams are butted against each other and taped, or overlapped and taped. This will reduce the possibility of moisture condensation within the cavity and improve performance [16].

For Reflective system the application areas are unfinished walls, ceilings, and floors. The installation methods are foils, films, or papers fitted between wood-frame studs, joists, and beams. The advantages are suitable for framing at standard spacing. Bubble-form suitable if framing is irregular or if obstructions are present, all most effective at preventing downward heat flow, however, effectiveness depends on spacing, and easy to apply [13].

2.4 Sprayed-Foam and Foamed-In-Place Insulation

Liquid foam insulation materials can be sprayed, foamed-in-place, injected, or poured. Their ability to fill even the smallest cavities gives them twice the R-value per unit length than traditional batt insulation.

The application areas of sprayed foam and foamed in place insulation are in enclosed existing wall or open new wall cavities; unfinished attic floors. And the installation methods of it applied using small spray containers or in larger quantities as a pressure sprayed (foamed-in-place) product. The advantages are good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions [17].

Most foam materials can now be used with foaming agents that don't use chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs), which are harmful to the earth's ozone layer.

Some types of available liquid foam insulation materials include follows:

- Cementitious
- Phenolic
- Polyisocyanurate
- Polyurethane.

Cementitious Foam

Cementitious insulation that is foamed and pumped into closed cavities. The initial consistency of the foam is similar to shaving cream and after curing is similar to a thick pudding. It is easily damaged by water since it is made from minerals extracted from seawater. It is non-toxic and doesn't burn [18].

Phenolic Foam

This type of foam was somewhat popular years ago as a rigid foamboard insulation. It is currently available only as a foamed-in-place insulation. One major disadvantage of phenolic foam that it can shrink up to 2% after curing. This makes it less popular today.

Some less common types include Icynene foam and Tripolymer foam. Icynene foam can be either sprayed or injected, which makes it the most versatile. It also has good resistance to both air and water intrusion. Tripolymer foam—a water-soluble foam—is injected into wall cavities. It has excellent resistance to fire and air intrusion.

Liquid foam insulation—combined with a foaming agent—can be applied using small spray containers or in larger quantities as a pressure-sprayed (foamed-in-place) product. Both types expand and harden as the mixture cures. They also conform to the shape of the cavity, filling and sealing it thoroughly.

Slow-curing liquid foams are also available. These foams are designed to flow over obstructions before expanding and curing, and they are often used for empty wall cavities in existing buildings. There are also liquid foam materials that can be poured from a container [18].

2.5 Structural Insulating Panels (SIP)

Structural insulating panels (SIP) often consists of a foamboard core sheathed on one or both sides with plywood, oriented strand board (OSB), or gypsum board (drywall.) The insulation is usually polystyrene or isocyanurate, but foam-straw composites are sometimes used too.

Because of their structural strength, SIPs reduce the need for structural lumber, opportunities for air leaks. It is also faster to build SIP wall assembles than many other construction methods. Most comparison studies between stick-built and SIP house show significant energy saving with the SIPs. Because these panels also reduce sound transmission, some designers use them for interior partitions too.

SIP roof panels sometimes have a nailable layer only on one side. It's purpose is as a retrofit over an existing roof where additional insulation is desired but no attic exists under the roof deck. The insulated roof panels are also available with air channels just under the exterior sheathing for ventilated roof designs [15].

For Structural insulating panels (SIP) the application areas are unfinished walls, ceilings, floors, and roofs for new construction. They are connected together to construct a house. The advantages of SIP are built houses provide superior and uniform insulation compared to more traditional construction methods. They also take less time to build [13].

2.6 Insulating Concrete Forms (ICF)

An ICF system consists of interlocking foam board and occasionally hollow-core foam blocks. The foamboard forms are held vertical and parallel to each other by plastic or steel rods and ties. After adding the appropriate reinforcing steel rods (rebar) and poured concrete, the result is a very strong and insulated concrete wall. Such a building can be made from foundation to roofline. Some innovative builders make the roof of ICF as well.

Because of its flammability, any ICF exposed to the occupied space must be covered with an appropriate fire-resistant material. Most codes find 12.7mm (1/2 in) drywall acceptable. The exterior of the building can be finished with anything the designer finds desirable.

Other systems use the rigid insulation board in the center of the concrete wall. These are often referred to as "tilt-wall" construction. The walls are poured in a form on a flat deck and after curing are "tilted" upright into position by a crane. Because the insulation board is inside the wall it reduces problems relating to fire and insect infestation.

Insulation block systems are typically hollow core polystyrene blocks that interlock to create the ICF wall system. Steel reinforcing rods are often used inside the block cavities to strengthen the wall. One draw-back of stacked block ICFs is that the foam webbing around the concrete filled cores provides easy access for insects and ground water to enter the building. To minimize these problems, some manufacturers make insecticide treated forms and often promote a water proofing method for the foam blocks [15].

2.7 Loose-Fill Insulation

Loose fill insulation is made from glass fiber or mineral wool fibers that have been chopped into small pieces. It can also be produced from chopped polystyrene or cellulose fiber. Cellulose fiber is made from recycled newsprint that has been treated with fire retardants and other chemicals to prevent deterioration.

Loose-fill insulation is blown into horizontal spaces such as floors or ceilings with special equipment. It must be installed to the density recommended by the manufacturer.

The use of loose-fill in spaces other than horizontal, only in the following situations:

- Water repellent loose-fill insulation may be used between the outer and inner of masonry cavity walls.
- Loose-fill insulation may be added to wood-frame walls of existing buildings (doing this will change the thermal gradient of the wall assembly and there fore, to prevent condensation, the vapor resistance of the wall should be verified before insulating).
- Loose-fill insulation can be used in attic spaces over ceilings sloped.
- Blown-in insulation can be used in above-ground wood frame walls of new construction (provisions must be made for inspection, avoiding settlement in the insulation, allowing ease of interior finish application and avoiding use of water in the insulation unless it can be shown that the water will not adversely affect other materials) [19].

Figure 2.6: Loose Fill Insulation.

For loose fill insulation the application areas are in enclosed existing wall or open new wall cavities, unfinished attic floors, hard-to-reach places. The insulation methods include blowing into place using special equipment; sometimes pouring in. The advantages are good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions [13].

2.8 Expanded Polystyrene Foam (EPF)

Expanded polystyrene foam (EPF) is a plastic material that has special properties due to its structure. Composed of individual cells of low density polystyrene, EPF is extraordinarily light and can support many times its own weight in water. Because its cells are not interconnected, heat cannot travel through EPF easily, so it is a great insulator. EPF is used in flotation devices, insulation, egg cartons, flats for meat and produce, sandwich and hamburger boxes, coffee cups, plates, peanut packaging, and picnic coolers, and in insulation inverted roofs. Although it is generally called Styrofoam, Styrofoam is a trademark of Dow Chemical Company and refers specifically to a type of hard, blue EPF used mainly in boating [20].

2.9 Extruded Polystyrene Foam (XPS)

Extruded polystyrene foam (XPS) maintains its excellent insulating power over time, resists moisture absorption and has compressive strength that, when compared to other insulation products, is second-to-none.

Many of the advantages of XPS foam are due to the extrusion manufacturing process employed.

XPS insulating materials are available in either rigid board stock or fanfold sheet versions and in a wide range of sizes, thickness and compressive strengths that are ideally suited to a variety of construction applications.

Following are some benefits and uses of XPS insulation:

Other materials provide insulation, but none maintain R-value as well as XPS over time. The high moisture resistance and high compressive strength of XPS help to maintain high R-value for many years in the harsh conditions of real-world applications.

XPS insulating materials applied to masonry or concrete interior walls and roofs, XPS insulation can be used with furring systems or other attachment methods to provide energy efficiency. Because XPS is rigid and dimensionally stable.

XPS is the only insulation allowed by building code in below-grade horizontal applications, such as frost protected shallow foundations.

Other XPS applications include: earth shelters; swimming pools; recreational vehicles; agricultural buildings; low-temperature space; ice rinks; pre-cast concrete systems; plaza decks; highway insulation; and airport runway insulation [21].

2.10 Cellulose Insulation

Cellulose insulation is a smart alternative to fiberglass. It provides a green, efficient, non-toxic, affordable thermal solution that’s worth considering.

Cellulose is natural, It’s made of 80% post-consumer recycled newsprint. Cellulose insulation is safe. It is made of paper, but the chemical treatment provides it with permanent fire resistance. Many professionals consider cellulose to be more fire-safe than fiberglass. This claim rests on the fact that cellulose fibers are more tightly packed, effectively choking wall cavities of combustion air, preventing the spread of fire through framing cavities [22].

Figure 2.7 Cellulose Insualtion.

2.11 Nitrogen-Based Urea-Formaldehyde (UF) Foam

Urea-Formaldehyde (UF) foam was used in residential housing during the 1970's. However, after many health related court cases due to improper installation practices, it was removed from the residential market and is now used primarily for masonry walls in commercial/industrial buildings. This type of foam insulation uses compressed air as the expanding agent. Nitrogen-based, UF foam may take several weeks to cure completely. Unlike polyurethane insulation, this product does not expand as it cures and also allows water vapor to easily pass through it. UF foam also breaks down at prolonged temperatures above (190 F°) 88 C° and contains no fire retardant chemicals [15].

3. INSULATION APPLICATION IN BUILDINGS

Insulation specifications are an important design feature. A building envelope provides a barrier between the indoor and outdoor environments allowing the thermal comfort levels indoors to be adjusted to suit the occupants. This might require heating or cooling depending on the season and location of the building. The energy required for heating or cooling will be greatly reduced if the building envelope is adequately insulated. This means insulating the ceiling, walls and floor of the building, which is an easy task during construction, but often more difficult for existing buildings [23].

The building envelope is the area that separates conditioned space from unconditioned space. In Figure 3.1, the building envelope is the area surrounded by the insulation.

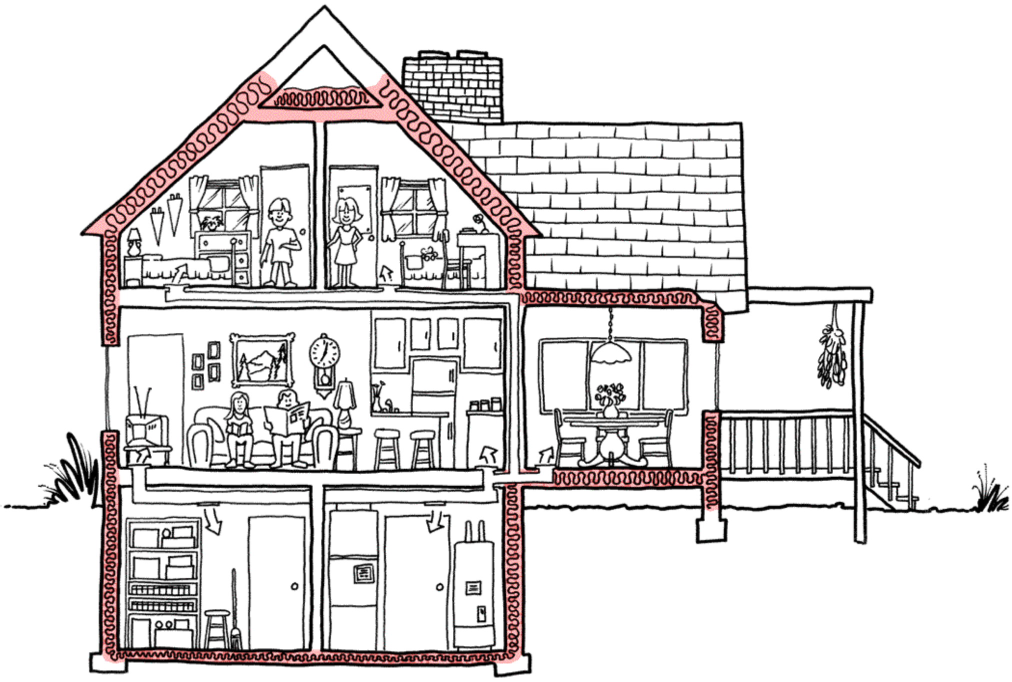


Figure 3.1: Application Area Surrounded by Insulation [24].

The following areas are the application areas that should be insulated in a building.

3.1 Ceiling and Roof Insulation

In summer, because of the hot summer sun, most of the heat gain in a building comes through the roof. In the winter, since heat rises, most of the heat loss is also through the roof.

If the weather gets hot, and cooling is a major problem, the specific way is to insulate the roof. This will block heat from getting into the building at all, stopping it at the roof line. If the weather gets very cold, and heating is a major expense, then insulate the ceiling. This will allow insulating and heating a smaller portion of the building, and saving energy costs.

The easiest time to install is during building construction, between the studs and metal. However, it's not much difficult to retrofit an existing building as well [25].

3.1.1 Ceiling Insulation

Insulating ceilings is one of the most cost effective energy efficiency measures. In addition to reducing heat loss in winter and heat gains in summer, ceiling insulation improves comfort by bringing ceiling temperatures closer to room temperatures and providing an even temperature distribution throughout the house.

Attic floors over flat ceilings are often the easiest part of an exterior building envelope to insulate; many homes use cathedral ceilings or have attic knee walls that present unique insulation requirements [26]. Figure 3.2 shows the application area of ceiling insulation.

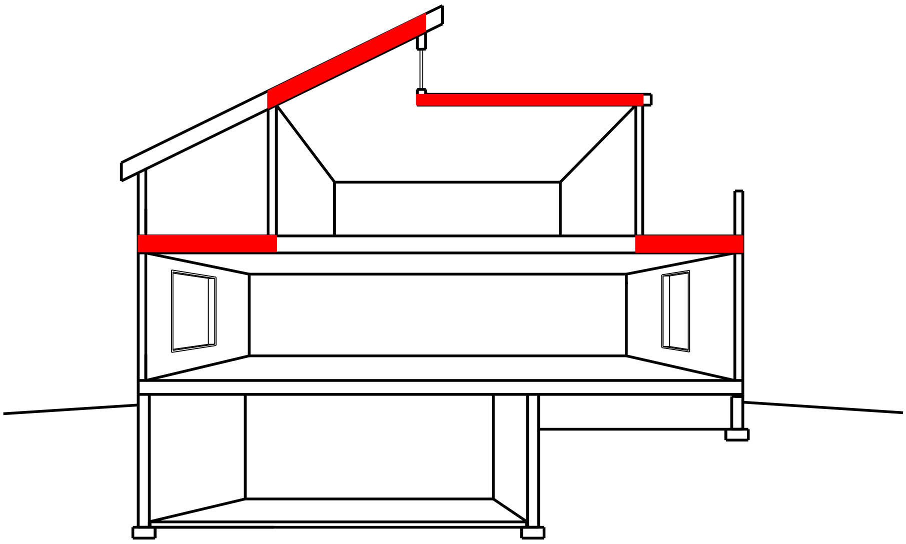


Figure 3.2: The Ceiling Application Areas Insulation [27].

3.1.2 Roof Insulation

Thermal considerations in the design of roofs can be divided into two general categories: The first one is the control of heat loss and heat gain of the space below the roof, and the second one is the effects of extremes and variations of temperature on the roof system. Where temperature control through winter heating and summer cooling is common, heat gain and heat loss are of economic importance. Some roofs may only control heat gain by providing shade from the sun, but all roofs exposed to the weather experience wide variations of temperature. The effects of extremes and variations of temperature are of major importance because they influence the durability of the total roof system. It must also be recognized that all materials interposed between environments, including ceilings and air spaces, are considered part of the roof system because all influence the thermal performance of the total construction [28]. Figure 3.3 shows the application area of roof insulation.

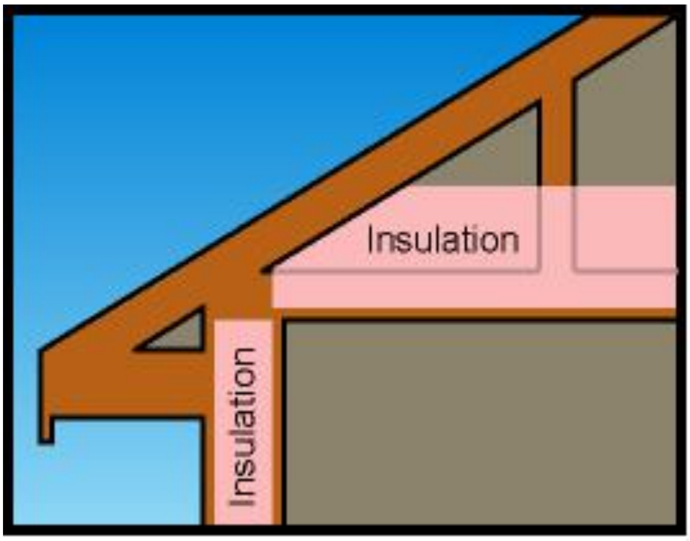


Figure 3.3: Application Area of Insulation in Roofs [27].

3.1.3 Loft Insulation

Insulating loft is a simple and effective way to reduce heating bills, and to save the energy, and it's easy to apply. In most cases the addition of loft insulation follows the manufacturer's instructions for the insulation material being used.

Insulation is simply laid over the floor of the loft, between and then over the joists if they are visible [29].

Figure 3.4: Loft Insulation.

3.2 Wall Insulation

If the building has insulation in the ceiling but not in the walls, over 50% of the heat loss can be through the walls. Properly sealed, moisture-protected, and insulated walls help to increase comfort, reduce noise, and save energy. However, walls are the most complex component of the building envelope to insulate, air seal, and control moisture. The keys to an effective wall are:

- Airtight construction—all air leaks sealed in the wall during construction and prior to insulation installation.
- Moisture control—exterior rain drainage system, continuous air barrier, and vapor barrier located on the appropriate side of the wall.
- Complete insulation coverage—advanced framing to maximize insulation coverage reduce thermal bridging, no gaps or compressed insulation, and continuous insulated sheathing [30].

Figure 3.5 shows the application areas of wall insulation. And Figure 3.6 shows a sample application of wall insulation.

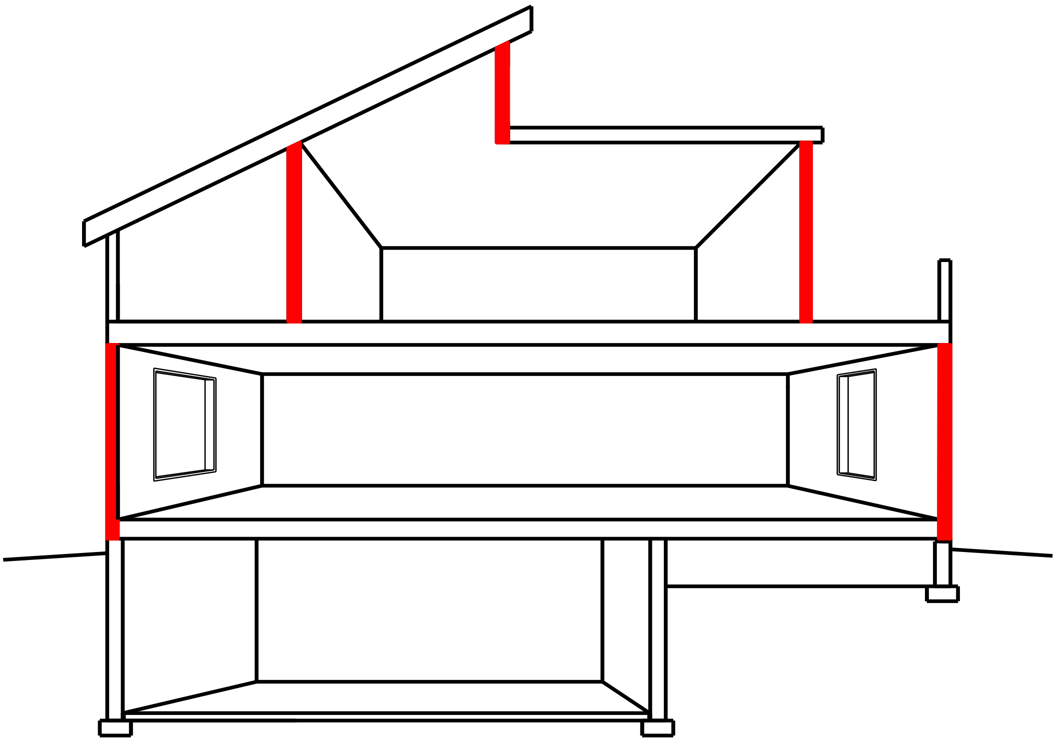


Figure 3.5: Application Areas of Wall Insulation [27].

Figure 3.6: Wall Insulated Internally [27].

3.2.1 Truss Walls Insulation

A truss wall system can provide greater thermal resistance than standard frame walls. It consists of a sheathed load bearing wall with trusses outside the wall which are supported at the lower end by a ledger. A truss wall is shown in Figure 3.7.

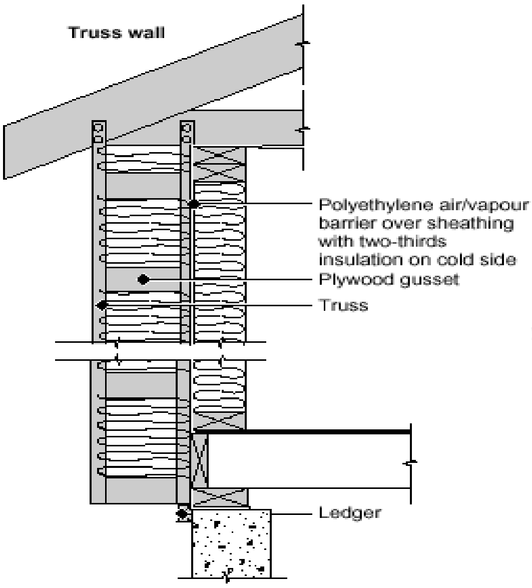


Figure 3.7: Truss Wall.

3.2.2 Stud Walls

Stud walls as shown in Figure 3.8 are usually insulated by installing flexible batt insulation between studs. Polyethylene sheets with sealed joints installed over the studs on the warm side act as both the air and vapour barrier.

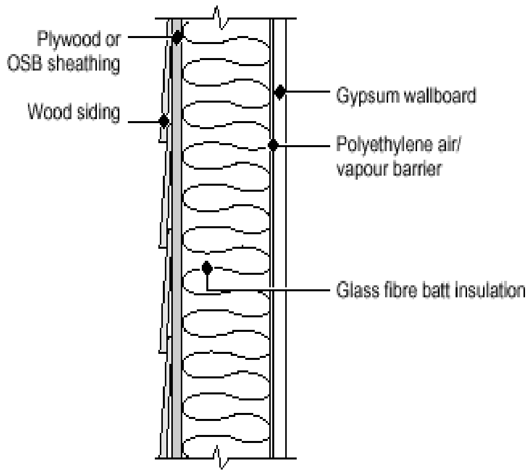


Figure 3.8: Stud Walls.

A common way to increase the insulating value of a stud wall is to use external thermal sheathing. The structural sheathing is replaced with rigid or semi-rigid insulation panels as it's shown in Figure 3.9. The panels can be nailed to the stud wall using special nails with large plastic washers.

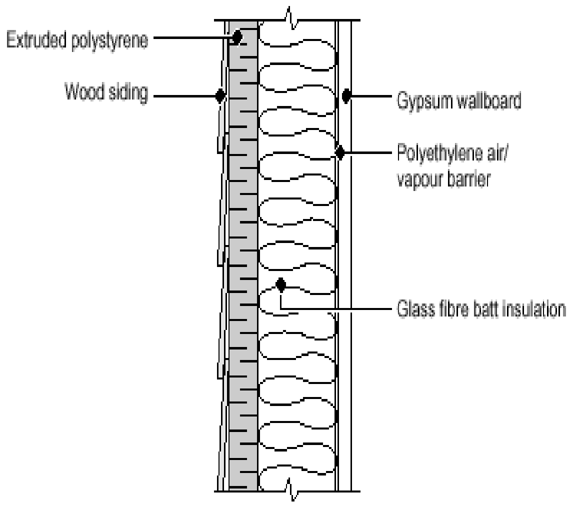


Figure 3.9: Stud Walls with Exterior Thermal Sheathing.

Wood-frame walls can be constructed with strapping on the interior of the studs to create a space for additional insulation, as it's shown in Figure 3.10.

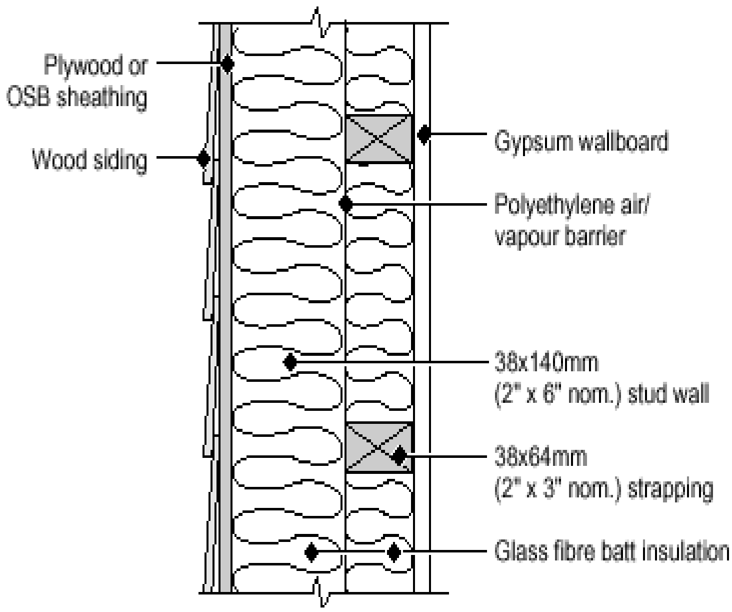


Figure 3.10: Stud Walls with Interior Strapping.

3.2.3 Cavity Wall Insulation

In the cavity walls filling the gap between the two walls of a house with an insulating material massively decreases the amount of heat which escapes through the walls.

Representations of cavity walls are shown in Figure 3.11. It will help to create a more even temperature in the house, help to prevent condensation on the walls and ceilings and can also reduce the amount of heat building up inside the house during summer hot spells [31].

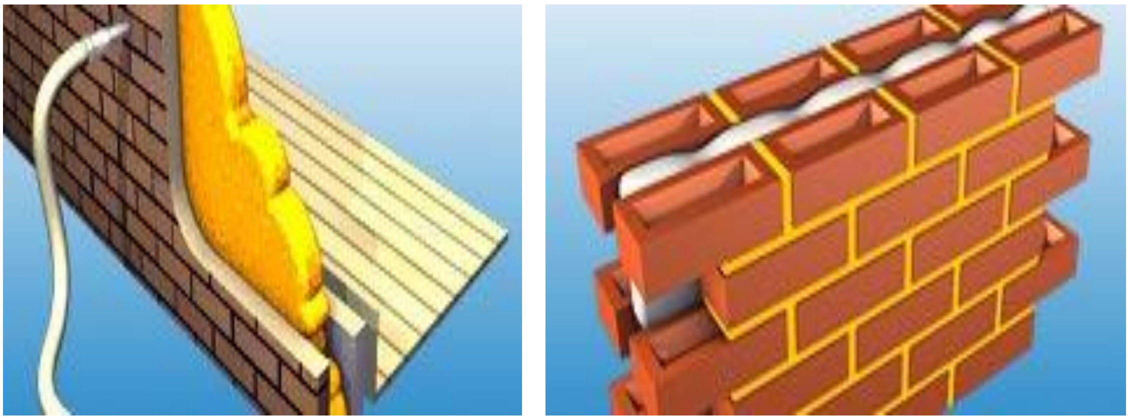


Figure 3.11: Typical Brick Formation for Cavity Walls [31].

Cavity wall insulation is quick, clean and relatively inexpensive to install. The insulation is injected into the cavity from the outside, as shown in Figure 3.12, taking between two and three hours in a three bedroom semi-detached house.

Figure 3.12: The Way to Insulate a Cavity Wall [31].

3.2.4 Solid Wall Insulation

There are two types of solid wall insulation, external and internal. Solid walls lose even more heat than cavity walls; the only way to reduce this heat loss is to insulate them on the inside or the outside.

This will help to create a more even temperature in the building, help prevent condensation on the walls and ceilings and can also reduce the amount of heat building up inside the building during summer hot spells [32]. Typical solid wall insulation is shown in Figure 3.13.

Figure 3.13: Typical Brick Formation for Solid Walls [32].

3.2.5 Crawlspace Wall Insulation

Although no crawlspace is used in the houses of North Cyprus, an illustration of the application is shown in Figure 3.14.

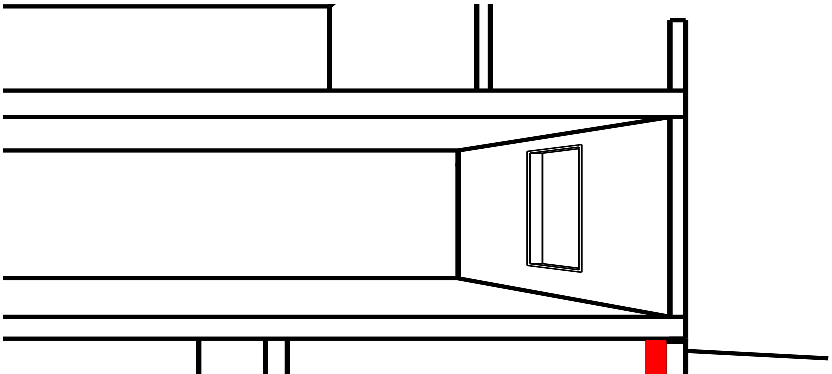


Figure 3.14: Application Area of Crawlspace Wall Insulation [27].

3.2.6 Basement Walls

When insulating a conditioned (heated or cooled) basement, only the walls need to be insulated. The basement ceiling may be insulated for noise control between floors [27]. Figure 3.15 shows the application area of basement wall. Figure 3.16 shows an exterior application where as Figure 3.17 shows an interior application.

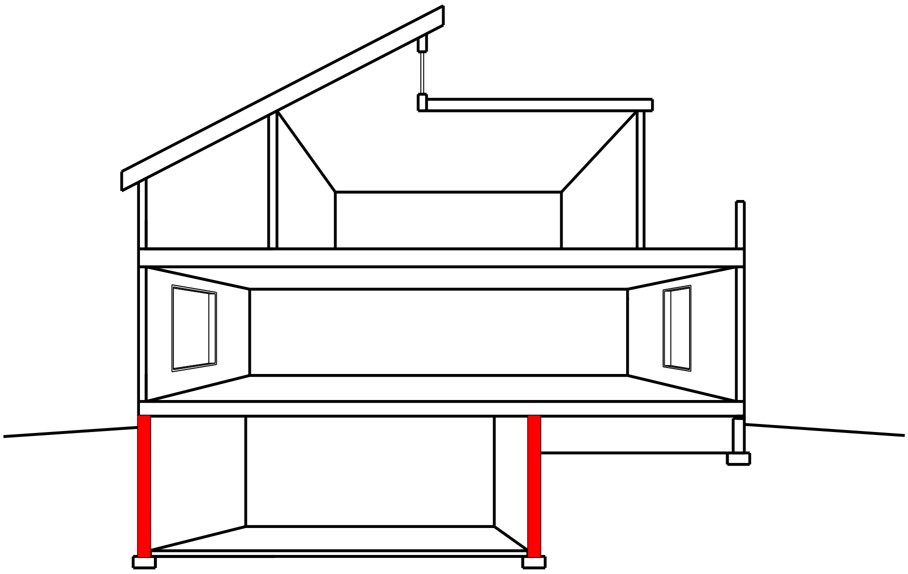


Figure 3.15: Application Areas of Basement Wall [27].

Figure 3.16: Insulating Basement Walls Externally [27].

Figure 3.17: Adding Insulation on Basement Walls Internally [27]**.**

3.2.7 Interior Studs

Application areas of interior studs insulation & its application are shown in Figure 3.18 and Figure 3.19 respectively. There are no application in North Cyprus.

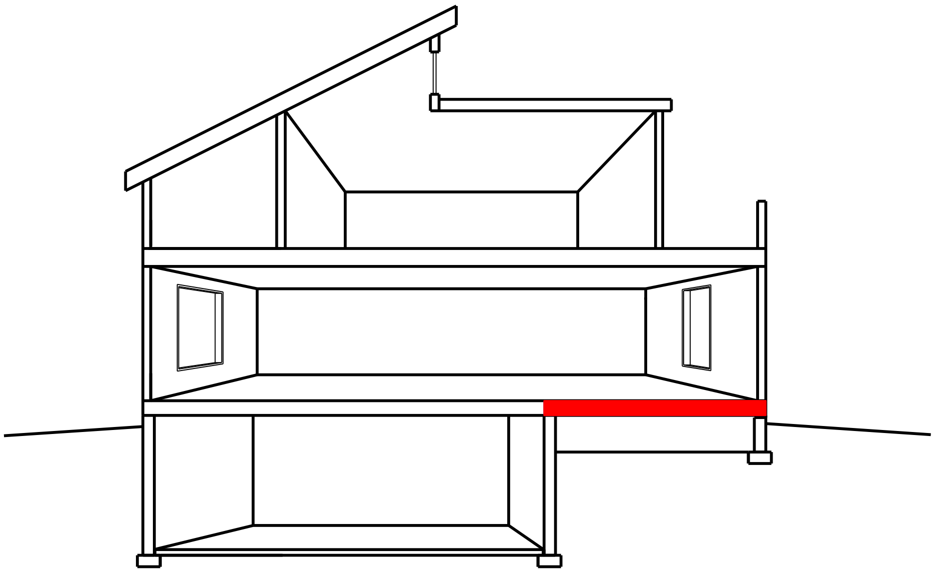


Figure 3.18: Application areas of interior studs insulation [27].

Figure 3.19: Adding an insulation material in an interior stud wall [27].

3.3 Floor Insulation

To insulate the floor in a building rises down the draughty. Rooms can sometimes feel cold due to draughts rising up from gaps between floorboards or between the skirting boards and the floor. Insulating material can be installed underneath ground floor floorboards and/or silicone sealant can be used to seal the gaps.

Floors can be insulated by lifting the floorboards and laying mineral wool insulation supported by netting between the joists [33]. Figure 3.20 shows a floor insulation application, this kind of this insulation not suitable for North Cyprus

Figure 3.20: Floor Insulation Application [27].

3.4 Windows (Glazing)

Single and double glazing windows are shown in Figure 21 and Figure 2.22, installing double glazing can reduce heat loss through windows by half. Double glazing works by trapping air between two panes of glass creating an insulating barrier that reduces heat loss, noise and condensation [34].

3.6.1 Single Glazing

Figure 3.21: Single glazing window [35].

3.6.2 Double Glazing

Figure 3.22: Double Glazing Window [35].

4. WORLD CLIMATES, GLOBAL WARMING AND CYPRUS

4.1 Introduction

Climate is the characteristic condition of the atmosphere near the earth's surface at a certain place on earth. It is the long-term weather of that area (at least 30 years). This includes the region's general pattern of weather conditions, seasons and weather extremes like hurricanes, droughts, or rainy periods. Two of the most important factors determining an area's climate are air temperature and precipitation.

The sun's rays hit the equator at a direct angle between 23 ° N and 23 ° S latitude. Radiation that reaches the atmosphere here is at its most intense. In all other cases, the rays arrive at an angle to the surface and are less intense. The closer a place is to the poles, the smaller the angle and therefore the less intense the radiation.

The climate system is based on the location of hot and cold air-mass regions and the atmospheric circulation created by trade winds and westerlies.

Trade winds at north of the equator blow from the northeast. At south of the equator, they blow from the southeast. The trade winds of the two hemispheres meet near the equator, causing the air to rise. As the rising air cools, clouds and rain develop. The resulting bands of cloudy and rainy weather near the equator create tropical conditions.

Westerlies blow from the southwest on the Northern Hemisphere and from the northwest in the Southern Hemisphere. Westerlies steer storms from west to east across middle latitudes.

Both westerlies and trade winds blow away from the 30 ° latitude belt. Over large areas centered at 30 ° latitude, surface winds are light. Air slowly descends to replace the air that blows away. Any moisture the air contains evaporates in the intense heat. The tropical deserts, such as the Sahara of Africa and the Sonoran of Mexico, exist under these regions.

The Earth rotates about its axis, which is tilted at 23.5 degrees. This tilt and the sun's radiation result in the Earth's seasons. The sun emits rays that hit the earth's surface at different angles. These rays transmit the highest level of energy when they strike the earth at a right angle. Temperatures in these areas tend to be the hottest places on earth. Other locations, where the sun's rays hit at lesser angles, tend to be cooler.

As the Earth rotates on it's tilted axis around the sun, different parts of the Earth receive higher and lower levels of radiant energy. This creates the seasons [35, 36].

4.2 Köppen Climate Classification Systems

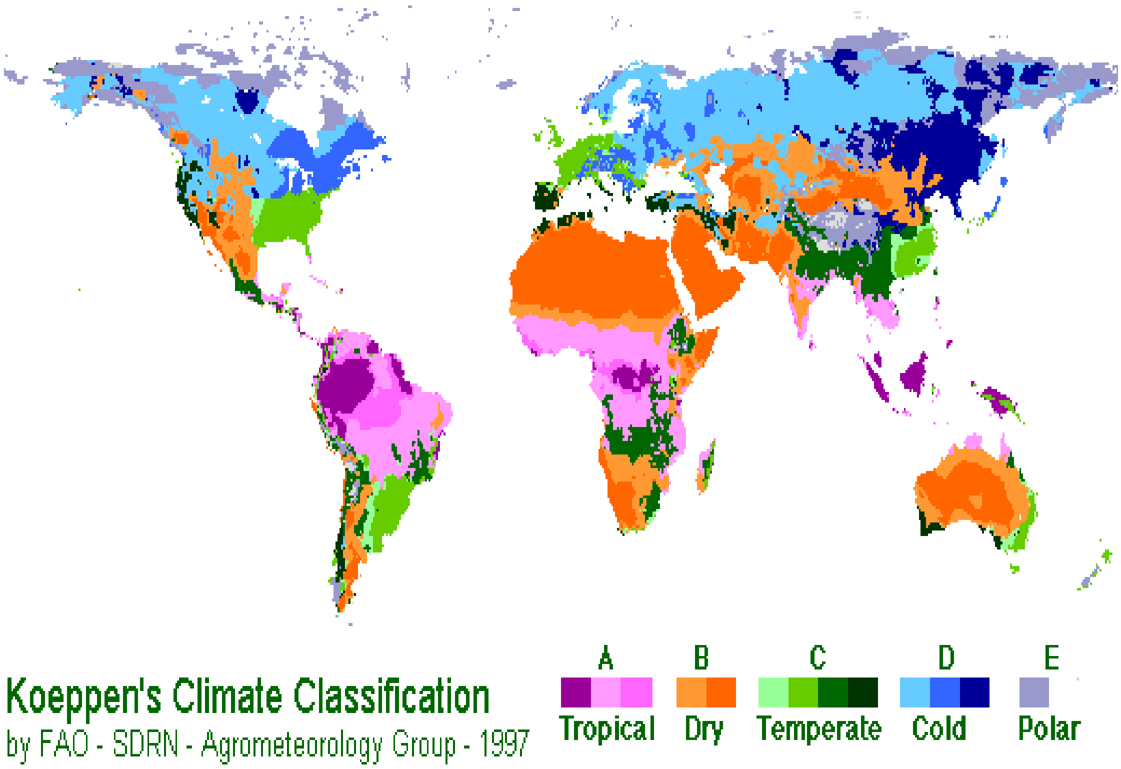


Figure 4.1: Koeppen’s Climate Classification.

The Köppen Climate Classification System is the most widely used for classifying the world's climates. Most classification systems used today are based on the one introduced in 1900 by the Russian-German climatologist Wladimir Köppen.

To further denote variations in climate, a third letter was added to the code.

a - Hot summers where the warmest month is over 22°C (72°F). These can be found in **C** and **D** climates.

b - Warm summer with the warmest month below 22°C (72°F). These can also be found in **C** and **D** climates.

c - Cool, short summers with less than four months over 10°C (50°F) in the **C** and **D** climates.

d - Very cold winters with the coldest month below -38°C (-36°F) in the **D** climate only.

h - Dry-hot with a mean annual temperature over 18°C (64°F) in **B** climates only.

k - Dry-cold with a mean annual temperature less than 18°C (64°F) in **B** climates only.

Global Range: Southwestern United States and northern Mexico; Argentina; North Africa; South Africa; central part of Australia. Figure 4.4 shows the general appearance of dry tropical climates.

Figure 4.2: Dry Tropical Climate (Bw) [37].

4.3 Group II: Mid-latitude Climates

Climates in this zone are affected by two different air-masses. The tropical air-masses are moving towards the poles and the polar air-masses are moving towards the equator. These two air masses are in constant conflict. Either air mass may dominate the area, but neither has exclusive control.

4.3.1 Group III: High-latitude climates

Polar and arctic air masses dominate these regions. Canada and Siberia are two air-mass sources which fall into this group. A southern hemisphere counterpart to these continental centers does not exist. Air masses of arctic origin meet polar continental air masses along the 60th and 70th parallels.

Figure 4.3: Highland Climate (H).

4.4 Global Warming and it's Effect

4.4.1 Global Warming

If the earth had an inert atmosphere, it would be a very cold, inhospitable place, with a global average air temperature of about -18°C. In fact, the global average temperature is between 14° and 15°C, because of global warming. In the hypothetical first case, all the energy in the sun's rays striking the earth's surface would heat it up (if the earth did not have a hot core and there were no sun, its temperature would be close to absolute zero). However, much of this energy would be radiated straight out again and equilibrium would be reached at -18°C. In reality, it is not like that, because of global warming, without which life as we know it could not exist. In fact, global warming has existed for many millions of years.

The analogy of a greenhouse explains this. All the sun's energy passes almost uninhibited through the glass and heats up the inside surfaces to above ambient temperature. However, glass will not allow the long wavelength energy which the warmed surfaces could radiate to escape, so the air inside the greenhouse also increases in temperature. So it is with the earth, except that we are not surrounded by glass but by certain gases which have the same effect of not allowing the energy stored in the earth's surface to escape into outer space. The average global temperature is in a careful equilibrium dependent on many factors and parameters. The concentration of these "greenhouse gases" (GHGs) is one such factor, and a very important one at that.

One of the most important greenhouse gas is water vapor, which averages about 1 per cent by volume over the planet. In terms of weather, the concentration is extremely variable from the dry air of a sirocco wind to a dank Scotch mist, but the average over time is very constant and is governed largely by evaporation from the oceans and vegetation. The quantity of water in the atmosphere is so great that man cannot change the overall global amount, not even by his worst efforts, so that a natural equilibrium pertains.

The next greenhouse gas and the most important from the point of view of climate change is carbon dioxide. The concentration of this has increased from 280 to 360 ppm in the last 125 years and this change is due to human activities, mostly burning extracted minerals, such as coal and oil, from where they have resided for millions of years under the earth's surface.

However, carbon dioxide and water vapor are not the only greenhouse gases, nor even the worst ones. If carbon dioxide is given an index of 1, called the Global Warming

Potential (GWP), representing the rise in resultant temperature for given mass, methane has a GWP of about 40, meaning it is 40 times worse. Fortunately, there is only about 0.00017 per cent of methane in the atmosphere, but that has more than doubled in the last 150 years, again because of man's activities. This is largely because of leaks of natural gas (increasing yearly), waste gases in petroleum refining, increased areas of rice paddies and increases in the numbers of cattle (enteric fermentation within a single cow will produce several liters of methane per day!), all of them resulting from human activities (on the other hand, draining wetlands would cause a slight reduction of natural methane).

Nitrous oxide has increased from 280 to 312 ppbv (parts per billion by volume) in the same period, relatively modest, in comparison. However, the worst of the lot are all man-made compounds, mostly containing fluorine. Hydro fluorocarbons (HFCs) often have GWPs between 500 and 2000; while per fluorocarbons (PFCs) may even exceed 10,000. Happily, the concentrations of these gases is still very low, a fraction of 1 ppbv. However, HFC production has increased enormously over the past two decades as a result of using them as substitutes for CFCs, banned by the Montreal Protocol. In particular, HFC-134a is a very popular gas for refrigeration and air conditioning [38].

4.4.2 Climate Change

Although the observations and the theory closely correlate. The evidence is circumstantial, but very strong. It is therefore reasonable to discuss the ramifications of this, as if it were proven. In the unlikely event of it being proved wrong, no harm will have resulted, only well, so it's a double-whammy in favor of action being taken.

Recent research (2004-2005) is tending to show the correlation between the emissions of man-made GHGs and the resultant effect on global climate is becoming stronger. Worse, a study by scientists at Oxford University is predicting a greater effect on climate than hitherto believed possible, with global temperature rises of up to a maximum of 11°C by the end of this century. This is based on the fact that polar and oro-glacial ice is already melting at a much faster rate that was previously forecast. If this extreme prediction came to pass, then life on earth, it is known today, will become very precarious and the human population decline may become much greater, because of famine and disease. It is thought that there is much more research necessary to be able to subscribe to the worst doomsday scenario, but must be discounted the possibility [38].

4.4.3 Probable Causes

The earth's climate and weather is the result of a delicate balance between a host of different natural phenomena:

- the greenhouse effect
- solar radiation
- the sunspot cycle
- elliptical orbits of the earth and moon
- wobble of the earth's axis
- the earth's magnetic field and positional polar changes
- ocean currents
- continental drift
- atmospheric convection cells, notably the Hadley cell
- photolysis and hydrolysis of organic matter
- volcanoes
- sulfate aerosols and other dust sources
- transpiration of living organisms
- forestation
- the size of the ice caps
- and many others.

A modification of any one of these may induce rapid changes of weather or slower changes of climate, depending on how and the length of time of the modification. Some changes may involve negative feedback, which will tend to restore the status quo while others may involve positive feedback which may tend to cause a runaway effect. As a hypothetical example of negative feedback, let us assume that the sun's radiation increases, causing a small rise of the temperature of the surface oceanic water; evaporation will increase, causing a heavier water vapor loading and more clouds form; the clouds have a high albedo and more radiation is reflected back into space, so the ocean water will tend to cool down again. An equally hypothetical example of positive feedback is that if a large tract of tropical rain forest were cut down for timber or to claim farm land, there will be a very reduced mass of vegetable matter and less transpiration will occur, resulting in lower regional rainfall; this will result in an inability of the remaining forest to sustain itself and it will slowly die off from the edges, causing desertification which will encroach continually and more rapidly until no rain forest is left.

What is sure is that the earth's regional climates do change, as is shown by the ice ages and by evident changes of vegetation over time. This is a perfectly natural phenomenon, usually taking many thousands of years.

What is equally sure is that the earth's average temperature, throughout the world, has increased by nearly 1°C over the past century or so. Never has such a change occurred in so short a length of time, since we have been able to follow the evolution of the earth's climate, dating back a few thousand years. As this is coincident with the increase of greenhouse gases caused by man's activities, the hypothesis of the latter being causal becomes inevitable. This has caused many of the world's most eminent atmospheric scientists to attempt to determine whether the observations result from the supposed cause. The main way that this has been tackled is to calculate mathematically all the potential identified causes, outlined in the above list, and their probable effect on the global temperature. Their results have been published in many scientific assessments and can be summarized by Figure 4.11 to Figure 4.13.

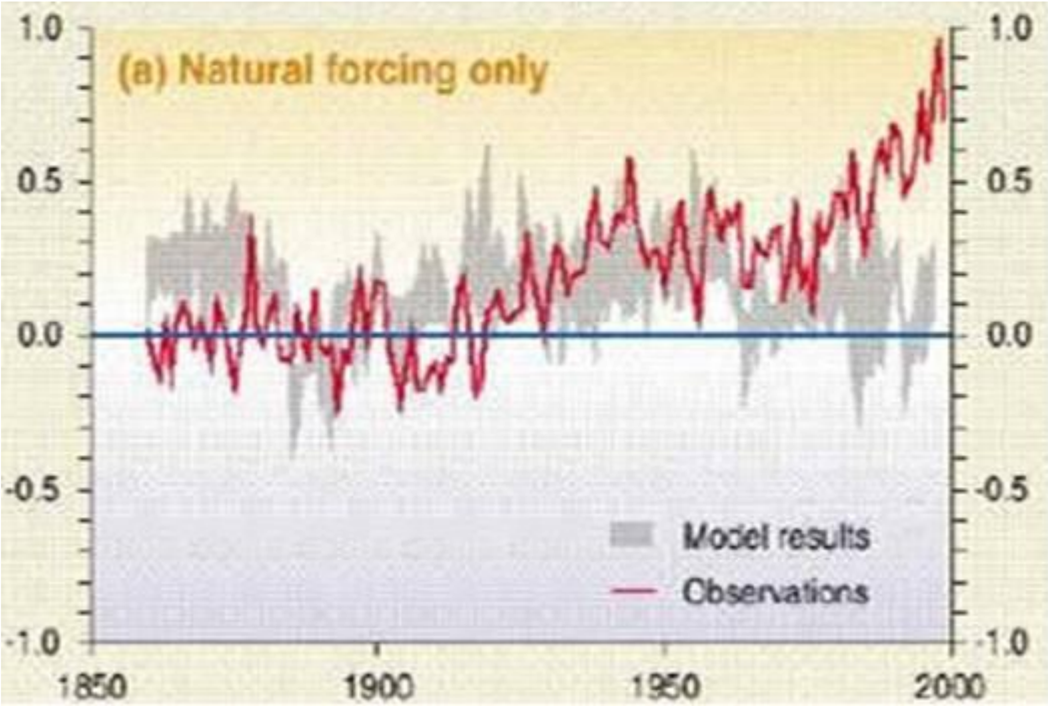


Figure 4.4: Temperature Anomalies in C° (Natural forcing only).

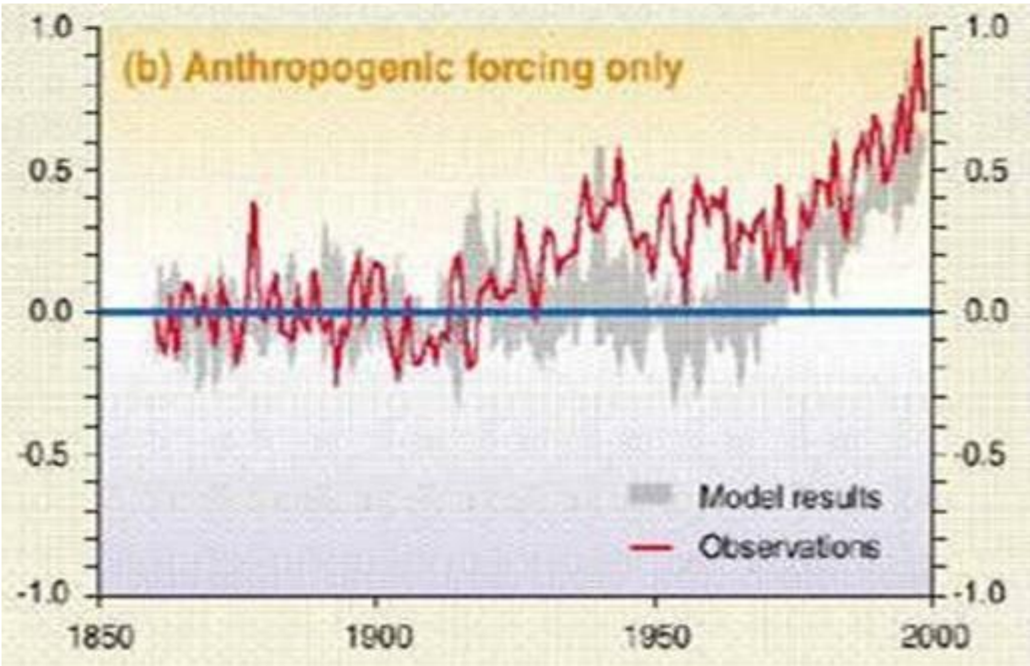


Figure 4.5: Temperature Anomalies in C° (Anthropogenic forcing only).

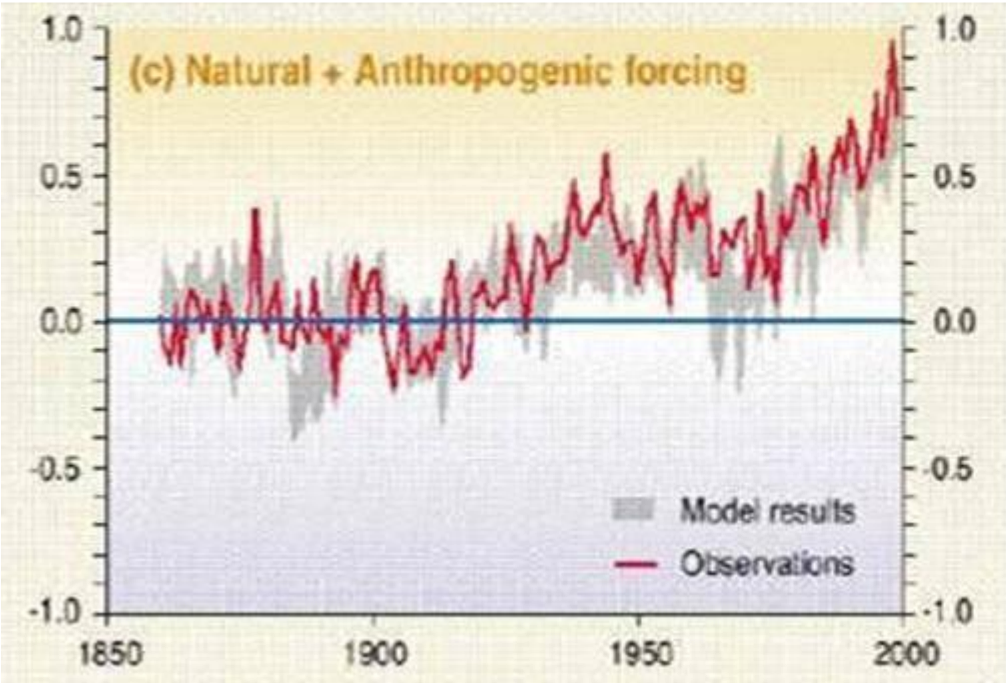


Figure 4.6: Temperature Anomalies in C° (Natural + Anthropogenic forcing).

These graphs were published by the Intergovernmental Panel on Climate Change (IPCC) under the auspices of the United Nations Environmental Programme (UNEP), which instigated this research. It can be seen, in Figure 4.11 that natural phenomena alone cannot explain the observed rise in temperatures, especially since 1950. Man-made greenhouse gases alone do not fit the observations, either, especially between 1930 and 1980, as shown in Figure 4.12. Combine the two, producing Figure 4.13, and the fit is visibly very good. Note that the model results take into account potential tolerances, due to incomplete knowledge (e.g., the tonnage of dust reaching the stratosphere from a violent volcanic explosion). The models take into account the minimum and maximum values, where there are uncertainties; therefore the grey lines in these graphs are broader than the observations line [19].

4.4.4 Possible Effects

The average climate change is causing several effects, some of them potentially severe. It does not really matter whether the change is caused by human activities, it is happening. The obvious ones have been mentioned in the press that we are all sick and tired of hearing them: ice cap melting, and low-lying land disappearing, increased desertification, biota changes, increasing violent weather phenomena etc.

The only statement that can result from this is:

If the changes are due partially to human activity, as seems most probable, then we should do everything in our power to reduce their effect as quickly as possible; if they are not due to this, then it will do no harm if we try to reduce their effect. In other words, we should do our best to restore the average climate to what it was over a century ago [38].

4.5 Climate of Cyprus and Global Warming

North Cyprus as well as the whole island enjoys typical Mediterranean climate with long warm and dry summers from mid-May to mid-October and mild and wet winters from December to February. The short autumn and spring periods complete the seasons of the year. Figure 4.14 and Figure 4.15 show the island Cyprus toghter with the Middle East countries, and map of Cyprus respectively. Table 4.1 gives the geographic proprieties of the island.

The Mediterranean climate is a form of temperate climate and is used to refer not just to the area around the Mediterranean Sea (including North Africa) but to similar climates around the world such as those in California, parts of Chile, south-west Australia and South Africa. All are characterised by hot summers and an abundance of sunshine all year. In winter, temperatures rarely drop below 5°C and are more likely to be in the region of 12° to 13°C while in summer averages can be up to 27°C. Frosts are very rare but there are unpleasent winds in a Mediterranean climate. The average monthly climate indicators in Nicosia can be seen in Table 4.2.

Figure 4.7: Map of the Middle East Countries.

Figure 4.8: Map of Cyprus [39].

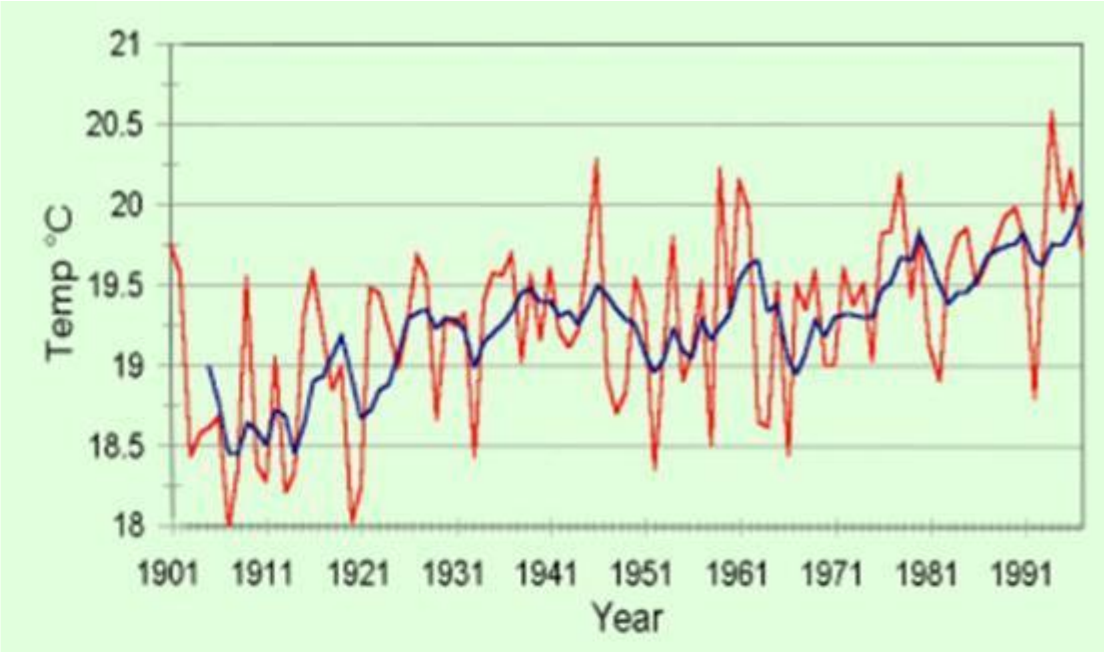
Table 4.1: Average temperature, rainfall and snowfall information is available for the following climate stations in Cyprus.

Name:	Turkish Republic of Northern Cyprus
Capital:	Nicosia
Area:	Total: 9,250 km^2 (of which 3,355 km^2 North Cyprus: 3355 km^2
Climate:	Temperate; Mediterranean with hot, dry summers and cool winters
Location:	Middle East, island in the Mediterranean Sea, south of Turkey
Geographic coordinates:	35 00 N, 33 00 E
Coastline:	648 km
Terrain:	Central plain with mountains to north and south; scattered but significant plains along southern coast
Elevation extremes:	Lowest point: Mediterranean Sea 0 m, highest point: Olympus 1,951 m

Table 4.2: The average monthly climate indicators in Nicosia based on 8 years of historical weather readings [40].

NICOSIA 35 15 N, 33 40 E, 161 meters (528 feet) above sea level.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Avg. Temperature (C^0)	12	12	15	20	26	30	32	32	28	24	17	13
Avg. Max Temperature (C^0)	14	15	18	23	29	33	36	36	32	27	20	16
Avg. Min Temperature (C^0)	5	5	6	10	15	19	21	21	18	15	10	6
Avg. Rain Days	5	3	3	1	1	0	0	0	0	1	3	3
Avg. Snow Days	0	0	0	0	0	0	0	0	0	0	0	0



—— : **Mean annual temperature.**

—— : **Average temperature Over 5 preceding years.**

Figure 4.9: Average Temperature in Cyprus [38].

It can see in Figure 4.16 that the average temperature in Cyprus has increased by a little over 1°C in the past century. The red line is the mean annual temperature and the blue line is the average over the five preceding years, which tends to smooth the curve. This does show that Cyprus has a hotter, drier climate than it had a century ago. This is serious because it means changes to our nature.

Note that the red line in Figure 4.13, between 1900 and 2000, is similar in shape and amplitude to the blue line in the average temperature curve for Cyprus of Figure 4.16. This shows that the changes we are experiencing are probably the same as in the rest of the world.

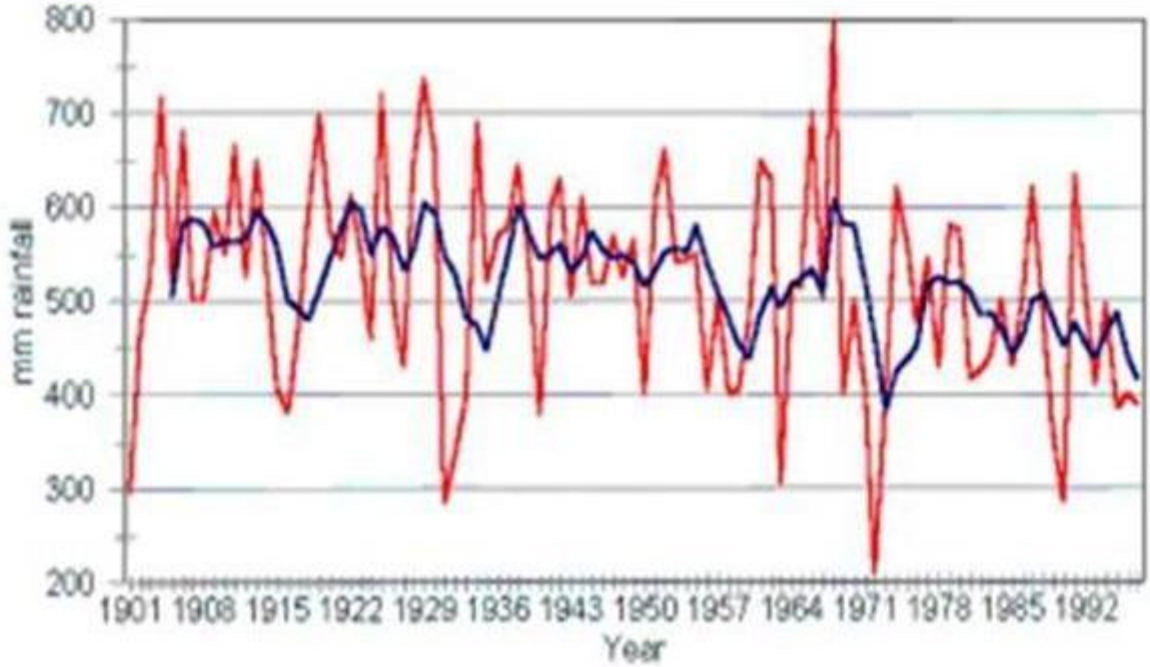


Figure 4.10: Rainfall in Cyprus by winter.

Over the same period, as it is shown in Figure 4.17 the rainfall has dropped by as much as about 100 mm or 20 %, although the fluctuations are much greater, even as much as in a ratio of almost 4:1. This is serious, because the population, and thus water demand, has increased by about 50 % since 1950, not counting an increased usage because of better hygiene [38].

5. THE CRITICAL IMPORTANCE OF BUILDING INSULATION FOR THE ENVIRONMENT

5.1 The Critical Importance of Building Insulation for the Environment

For the past 20 years, EURIMA (European Insulation Manufacturers Association) has studied the development of thermal insulation standards in new dwellings in Europe. Traditionally, these studies have focused upon the thickness of mineral wool insulation prescribed and applied in new construction. An updating survey completed in 2001, showed continued progress in insulation standards in several countries, particularly in central Europe. Unsurprisingly perhaps, in view of their climatic conditions, the Scandinavian countries – headed by Sweden – retain their position at the top of the list, showing how far the rest of Europe needs to go. The south continues to lag behind, despite European regulations demanding improved standards in order to meet Kyoto targets [41, 5]. The Kyoto Protocol is an agreement made under the United Nations Framework Convention on Climate Change (UNFCCC). Countries that ratify this protocol commit to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases[2]. The Kyoto Protocol now covers more than 160 countries globally and more than 60% of countries in terms of global greenhouse gas emissions [42].

The picture is the same for insulation thickness in walls and roofs. Although these previous studies give an accurate picture of the situation, the insulation thickness view is a rather simplistic one. It makes no attempt to weight the different countries, nor does it take into consideration their respective climates. In this new study, they have re-evaluated the figures in the different countries to take account of population sizes and degree days, i.e. the number of days per annum where heating is required. All performances are compared with Swedish standards [5].

Expressed in this way, the results throw new light upon the additional potential for energy savings in some northern countries, but they clearly indicate that the major efforts to save energy must be concentrated in the south and in countries with large populations. Significant progress could also be made in almost all European countries, by increased standards of insulation thickness in walls and roofs. For instance, applying Swedish levels of insulation in countries like Belgium, Spain and Italy, would yield savings in energy losses of up to 90%. Across Europe as a whole, energy savings in excess of 50% could be achieved by applying Swedish standards:

$U = 0.15\ W/m^2K$ for walls

$U = 0.10\ W/\ m^2K$ for roofs

Where, U is the overall heat transfer coefficient.

Countries with large populations such as the UK, Germany, France, Spain and Italy, represent the largest potential for energy savings. The total energy loss from dwellings is based on present day regulations for new construction. However, many old buildings have little or no insulation, and there is substantially greater potential for savings in the existing building stock. A multiplying factor of two to four could be applied to arrive at a more realistic figure of the actual loss, or potential energy saving, from dwellings.

Assuming that standards of living will grow, particularly in southern Europe, then tightening of insulation levels will be urgently required as energy consumption increases, e.g. by the increased use of air conditioning. Unless standards are improved, then the energy consumption required to increase comfort levels in dwellings will surpass the energy savings made through existing insulation levels. It's known that energy use in buildings accounts for more than 40% of all CO_2 emissions in Europe, but only Austria and the UK have plans for their buildings sector to achieve anything like 40% savings. So the challenge is to maintain pressure on national legislation to improve insulation standards. Contemporary studies of public attitudes to global warming and climate change also indicate poor awareness of the critical importance of buildings for the environment. People clearly still do not understand that their individual actions to improve building insulation can have a major impact on reducing CO_2 emissions [43].

Figures 5.1 to Figure 5.15 show the results of the studies of EURIMA for European countries including CO_2 emissions, energy losses and insulation thickness.

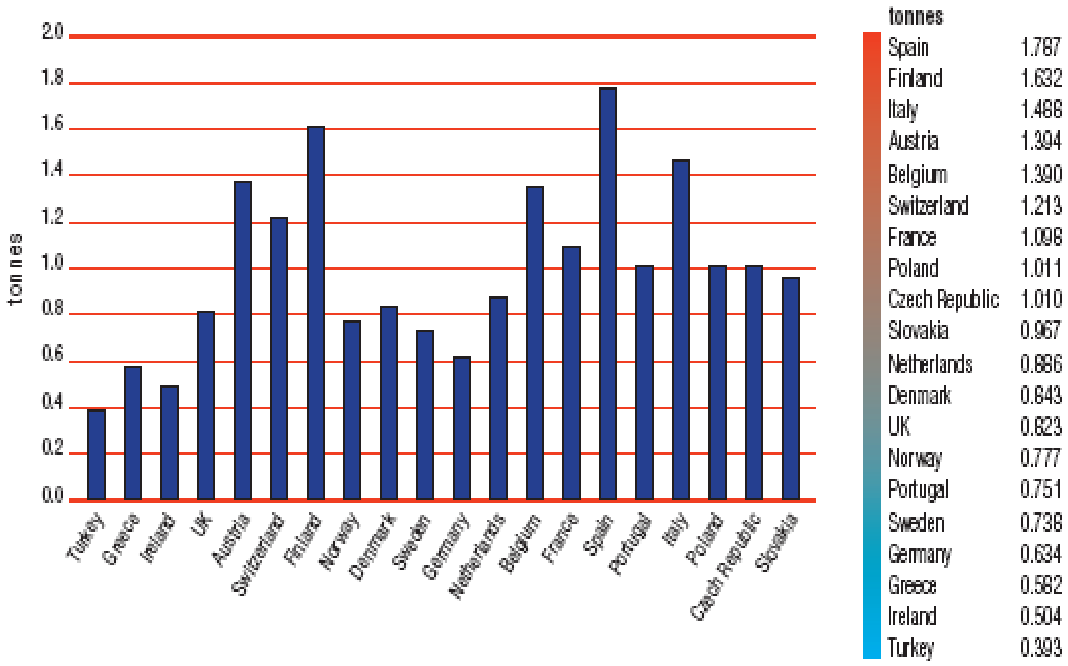


Figure 5.1: Per Capita CO_2 Emission per Year from Dwellings (tonnes).

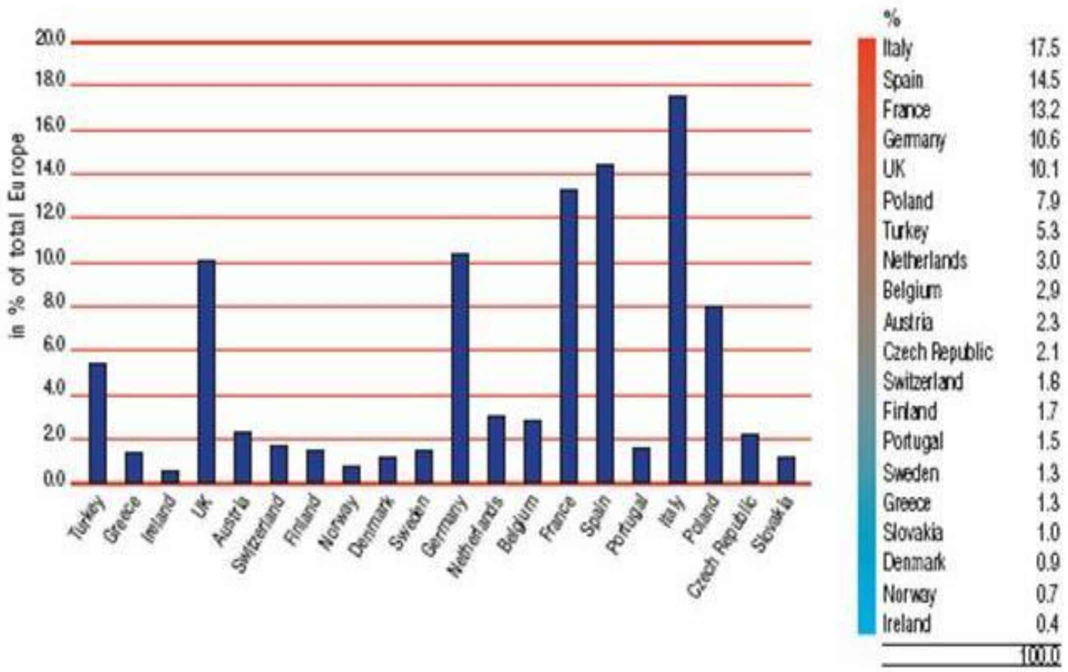


Figure 5.2: Total CO_2 Emissions per Year from Dwellings (%).

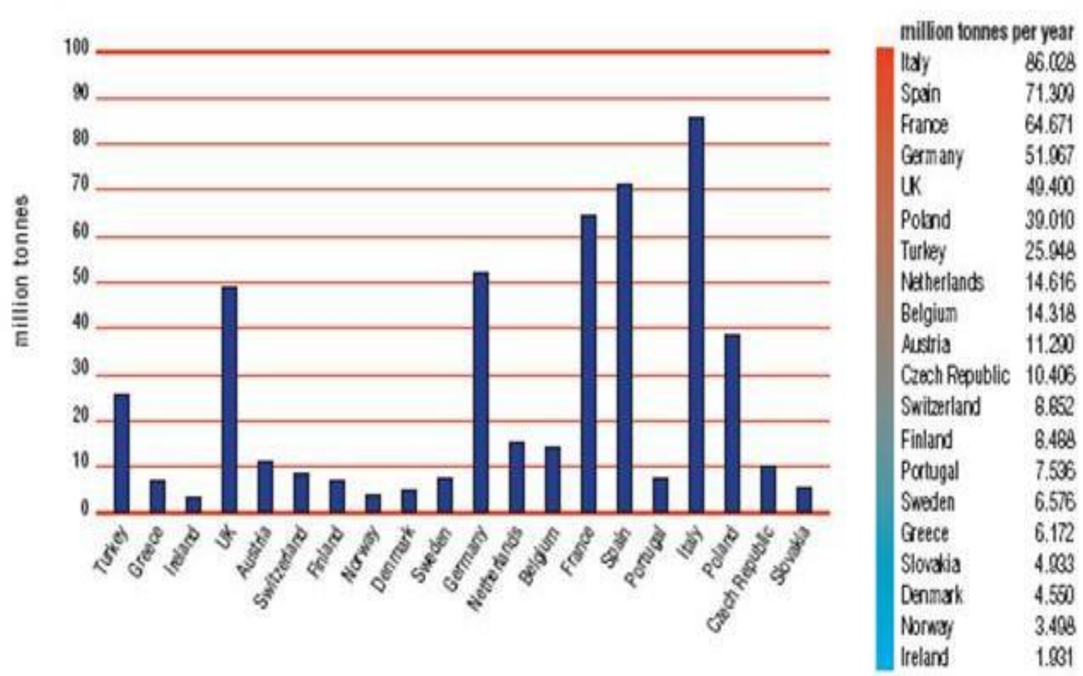


Figure 5.3: Total CO_2 Emission per Year from Dwellings (million tonnes).

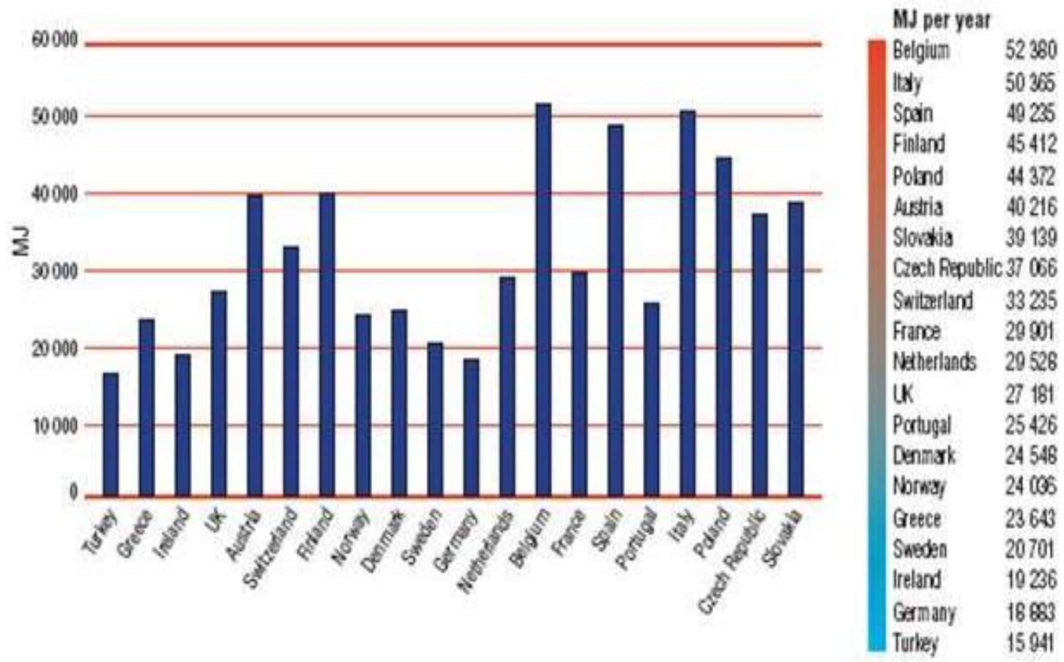


Figure 5.4: Energy Loss per Year per Dwelling (MJ).

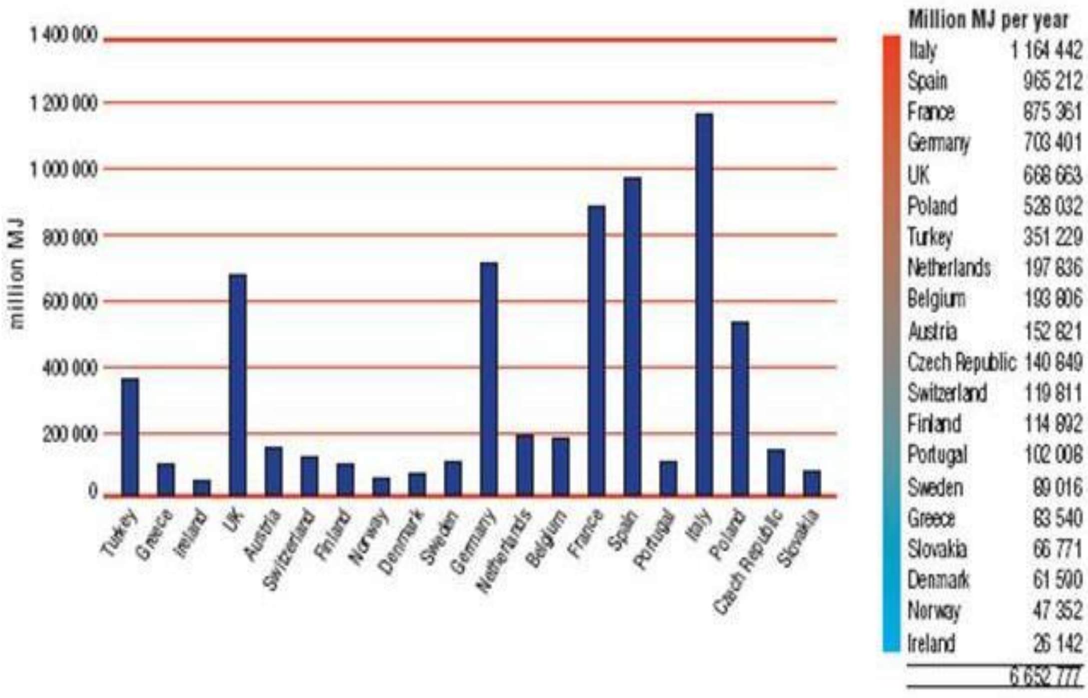


Figure 5.5: Total Energy Loss per Year from Dwellings (million MJ).

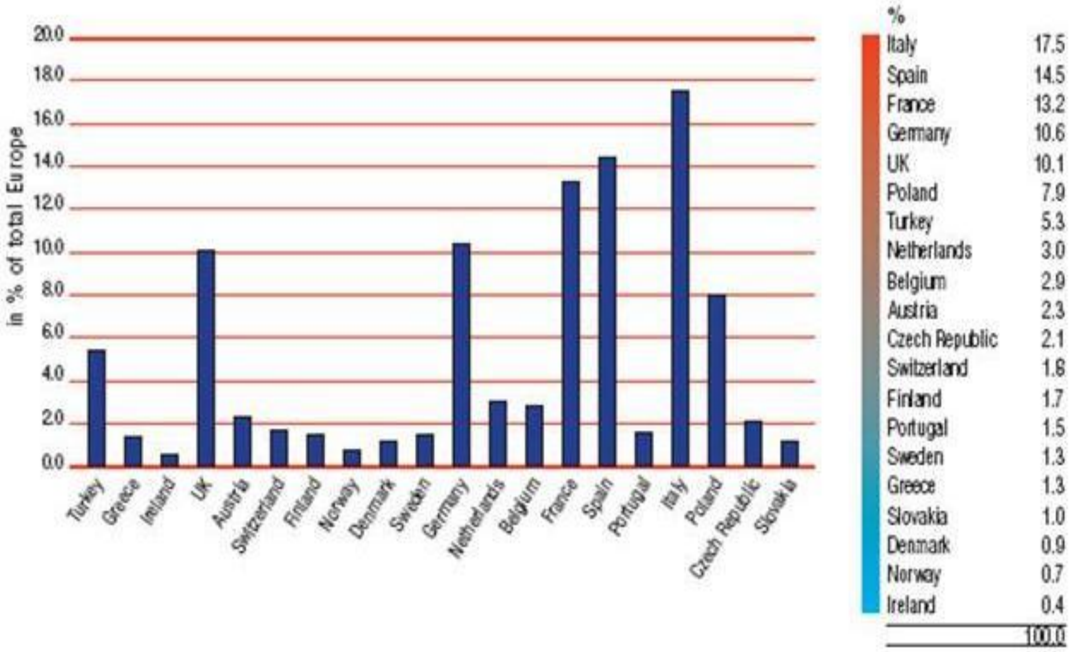


Figure 5.6: Total Energy Loss per Year per Dwellings (%).

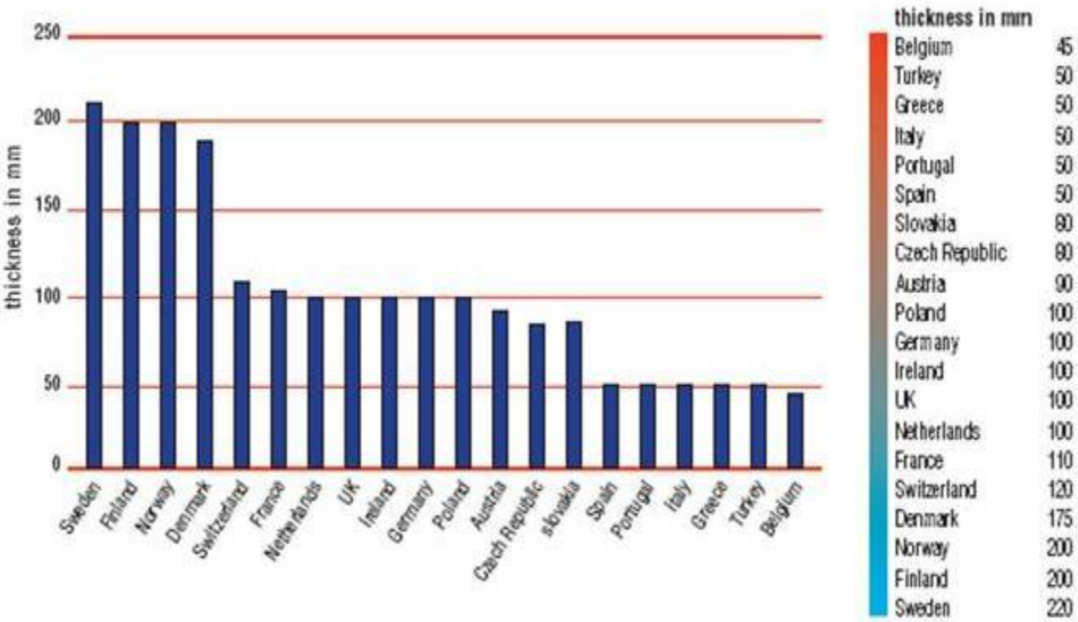


Figure 5.7: Insulation Thickness of Walls, 2001 (mm).

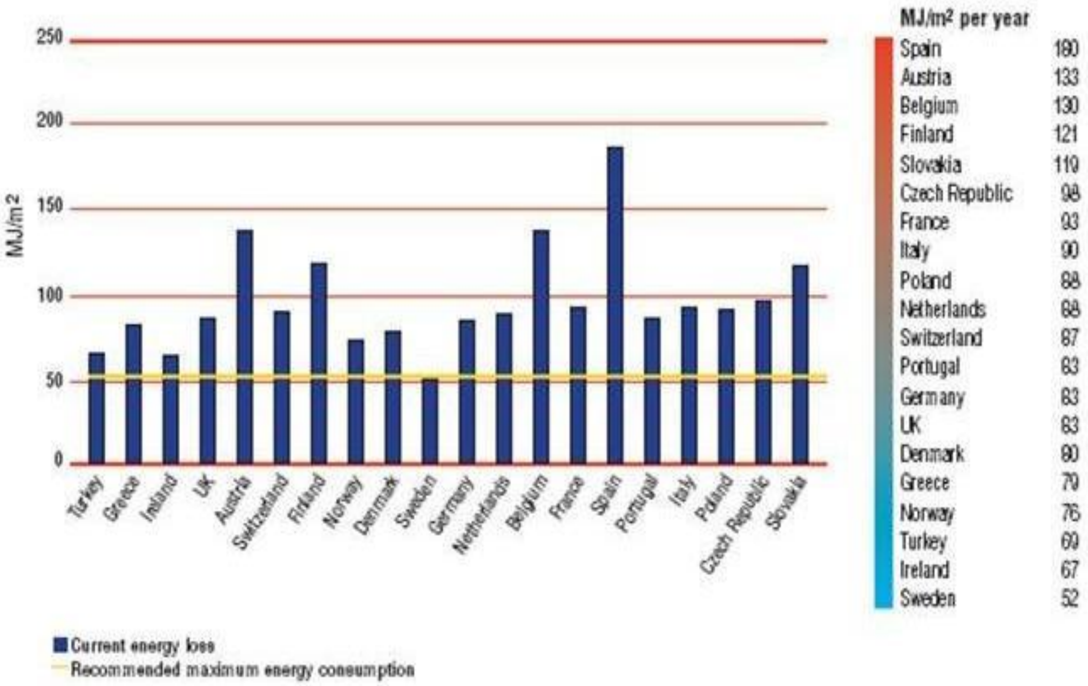


Figure 5.8: Energy Losses Through Walls, 2001 (MJ/m^2 year).

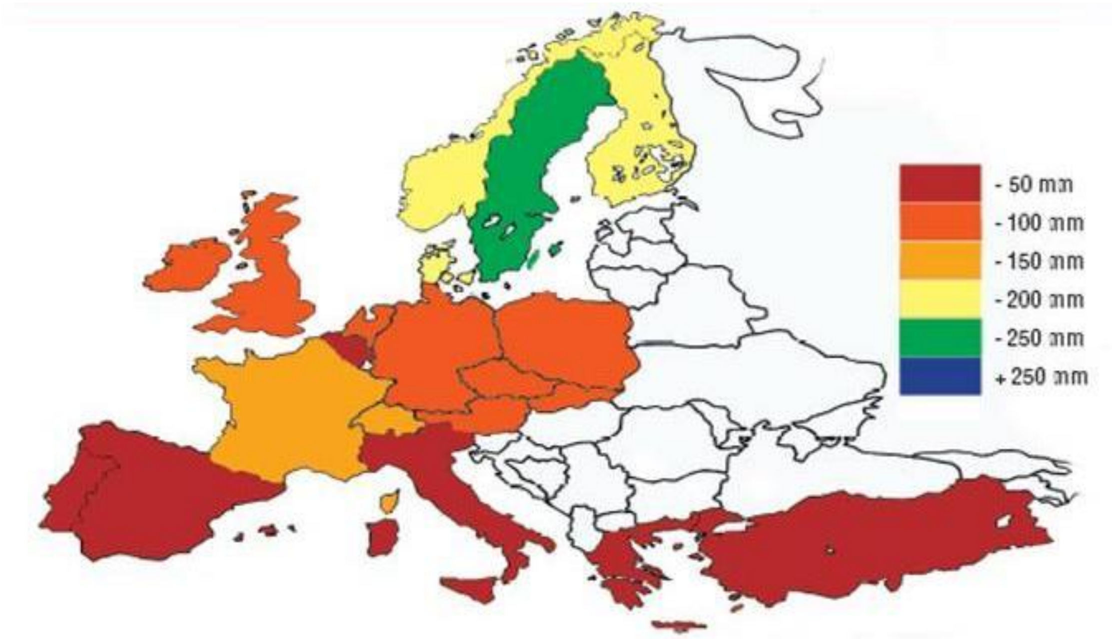


Figure 5.9: Insulation Thickness of Walls, 2001 (geographical).

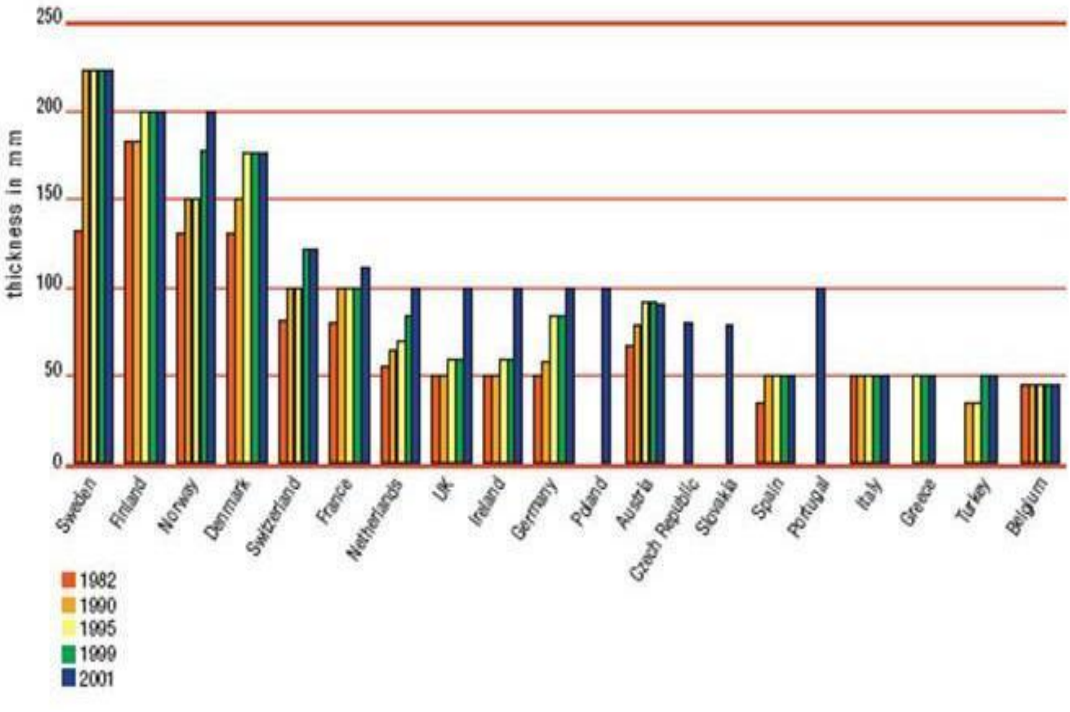


Figure 5.10: Insulation Thickness of Walls, 1982 to 2001 (mm).

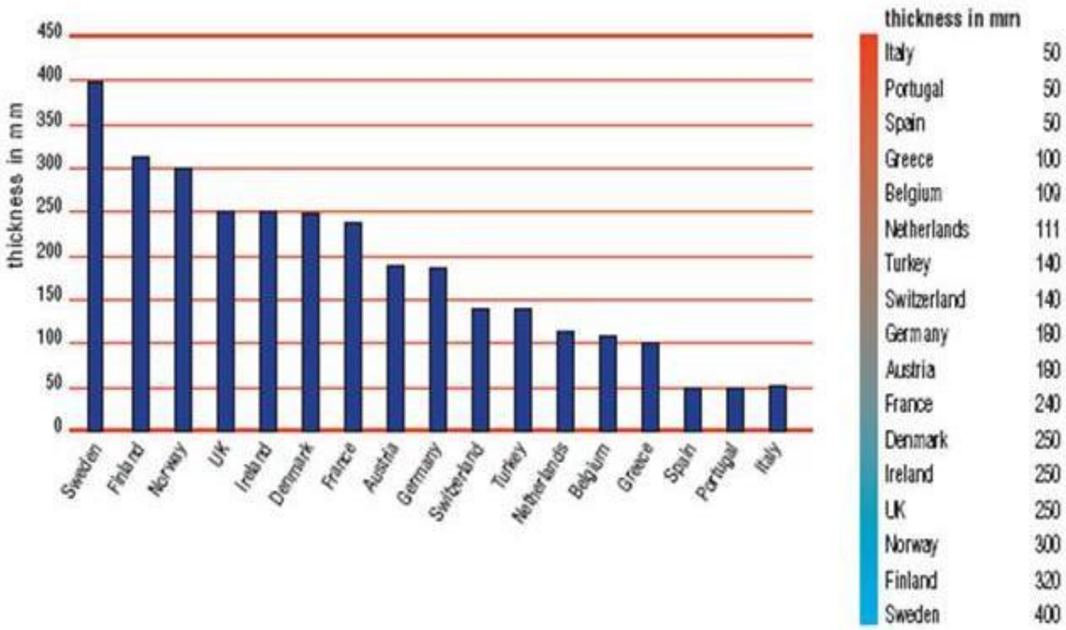


Figure 5.11: Insulation Thickness of Roofs, 2001 (mm).

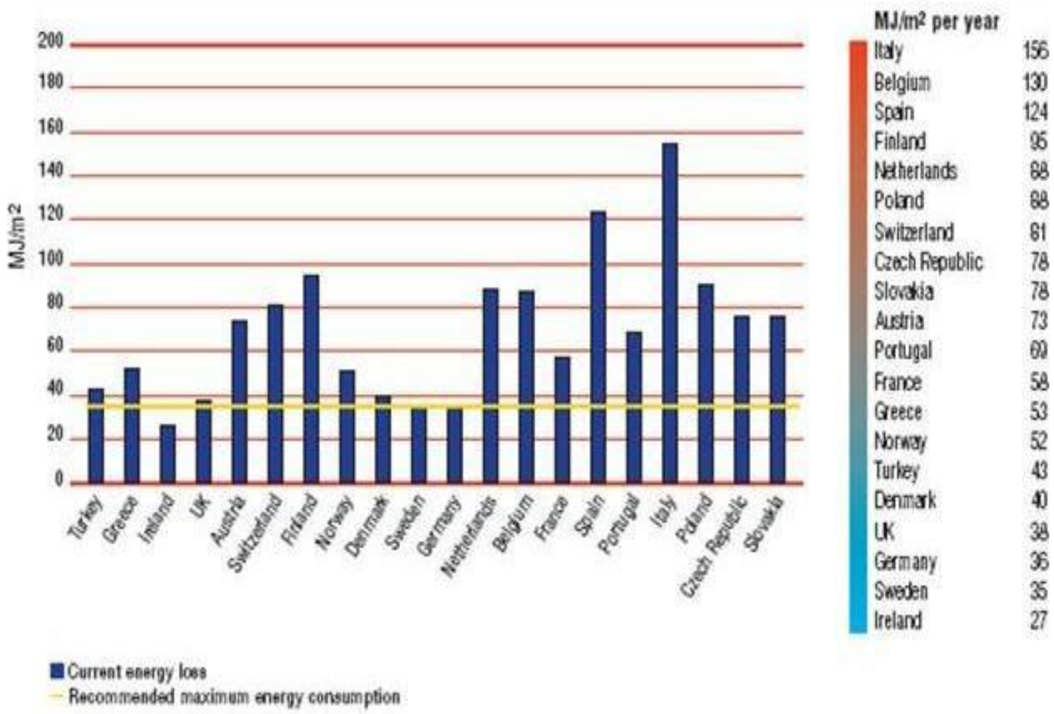


Figure 5.12: Energy Losses Through Roofs, 2001 (MJ/m^2 year).

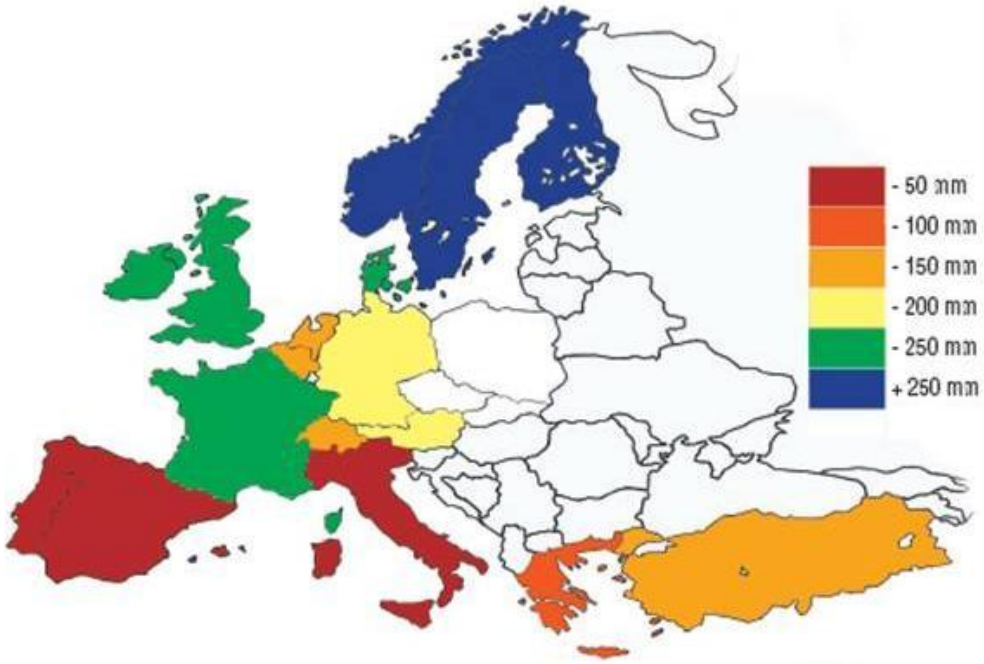


Figure 5.13: Insulation Thickness of Roofs, 2001 (geographical).

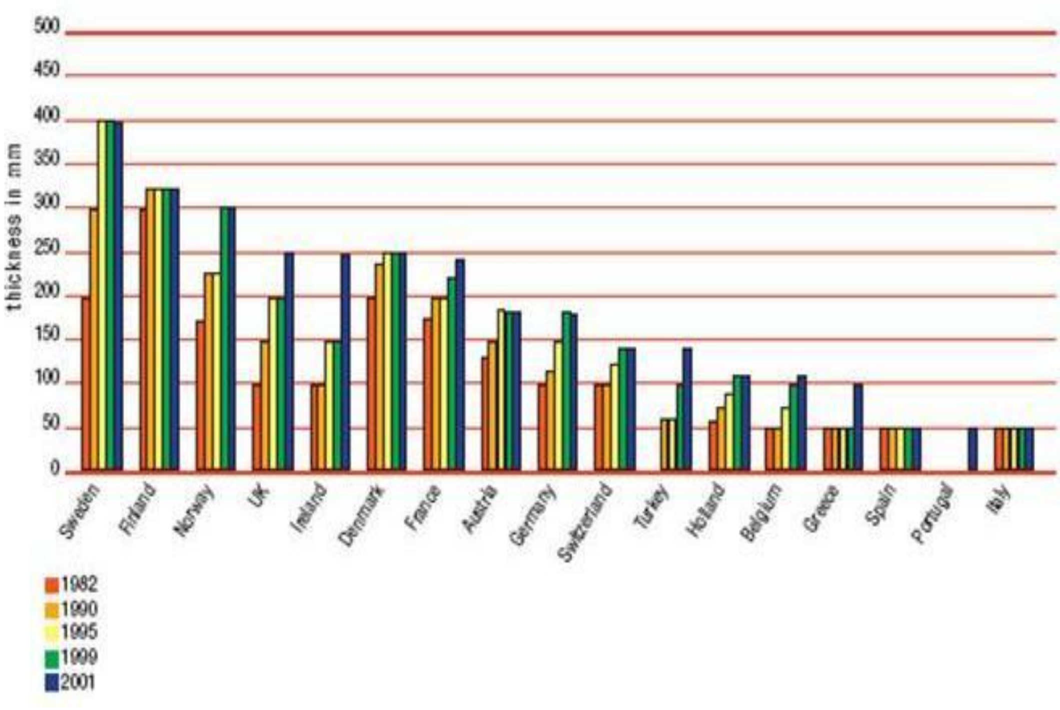


Figure 5.14: Insulation Thickness of Roofs, 1982 to 2001 (mm).

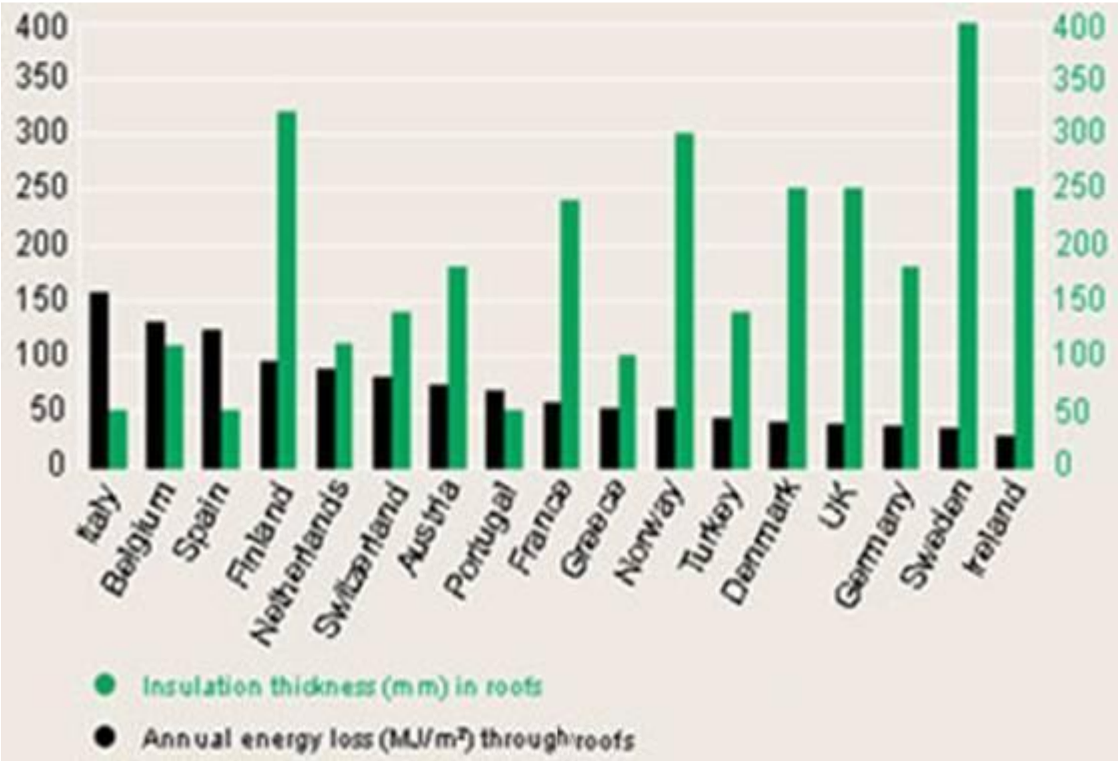


Figure 5.15: Energy Waste in Europe Though Roof.

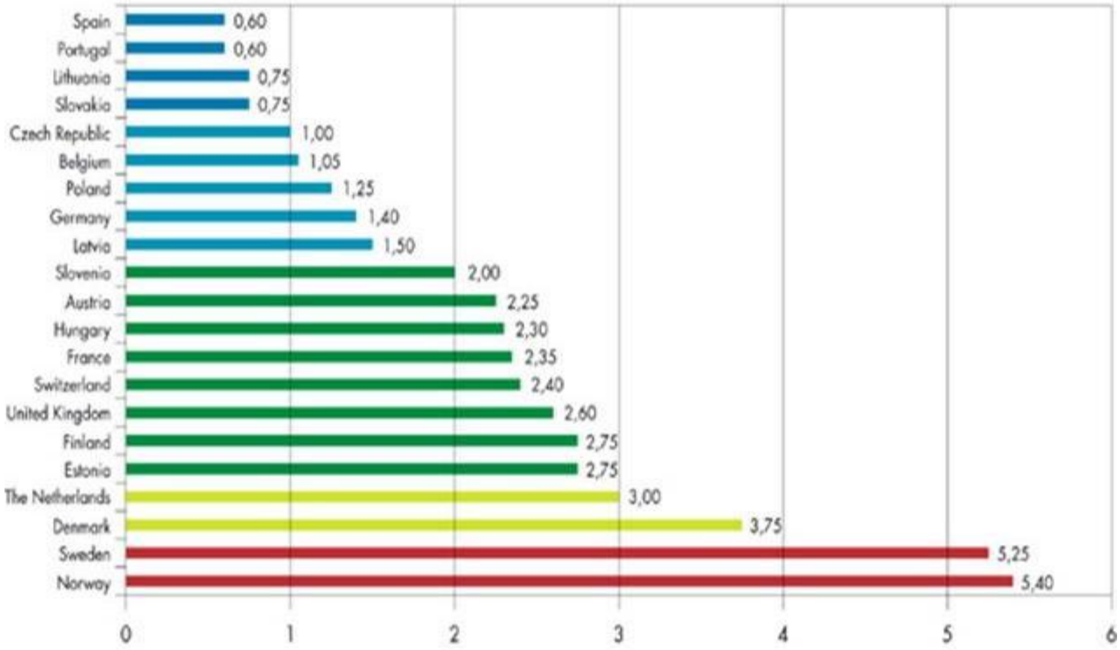
5.2 Overview of Applied Insulation Thickness in New Build Residential Buildings in 2004 in EU-Countries.

The survey on the insulation thickness was carried out by EURIMA members. It is based on manufacturers own data on the delivered insulation thickness for the market segment new build residential buildings and based on their survey of applied competitors products in this segment.

The survey covers the applied insulation thickness in the building envelop: for outer wall constructions, for roof construction and for ground floor constructions.

The market penetration of the different construction types and market shares of the different insulation types were calculated as a weighted average per segment. In order to have comparable figures for the different thermal performances per centimetre of thickness per insulation type the results of the average insulation thickness were normalized to a thermal performance based on a default thermal conductivity coefficient k=0,040 W/mK. In the following sections floor, roof and wall thermal resistance in insulation and insulation thicknesses are given for European countries.

5.2.1 Floor Insulation Applied Thermal Resistance in Insulation



R-Value [K/W]

Figure 5.16: Floor Insulation Applied Thermal Resistance in Insulation.

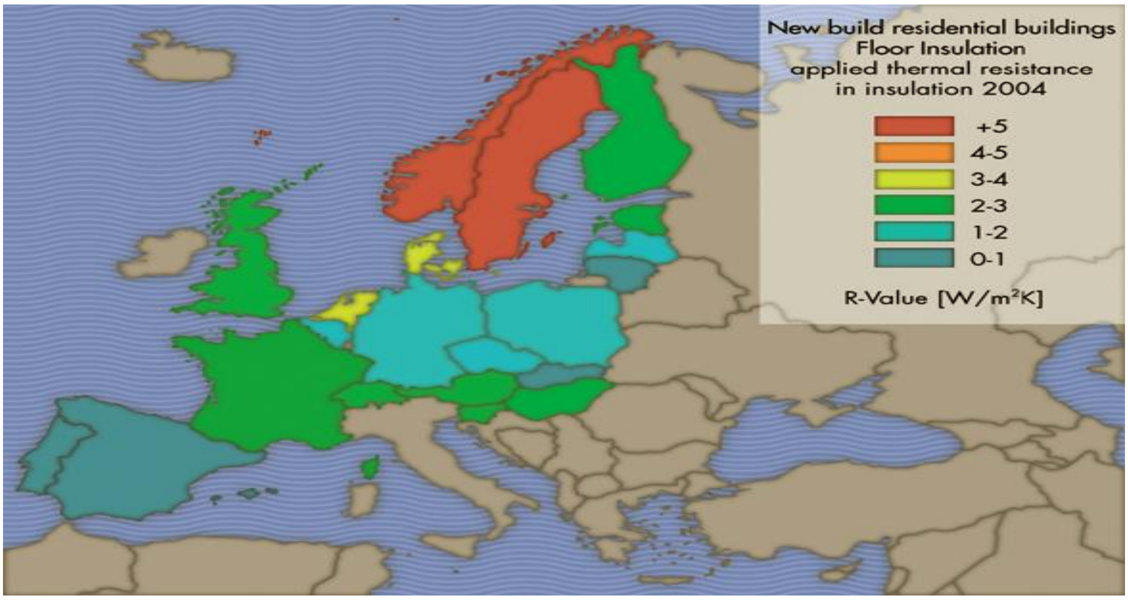


Figure 5.17: Map of EU of Floor Insulation Applied Thermal Resistance in Insulation.

5.2.2 Floor Insulation Applied Insulation Thickness

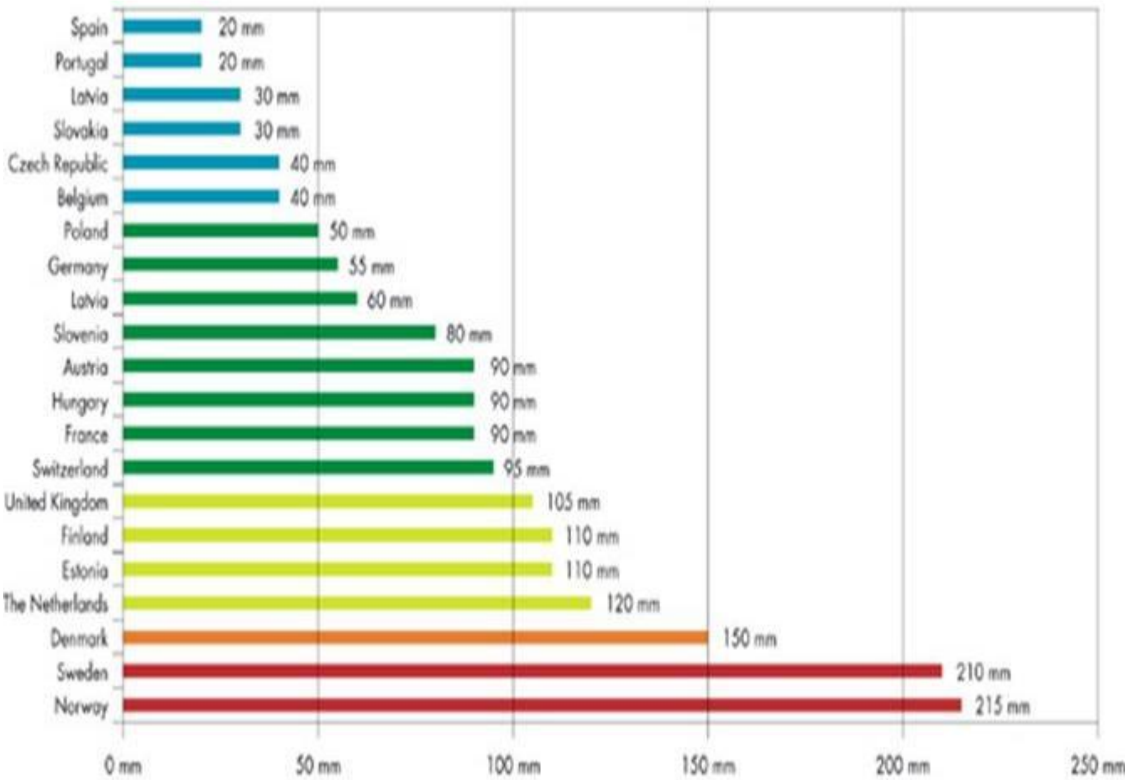


Figure 5.18: Floor Insulation Applied Insulation Thickness.

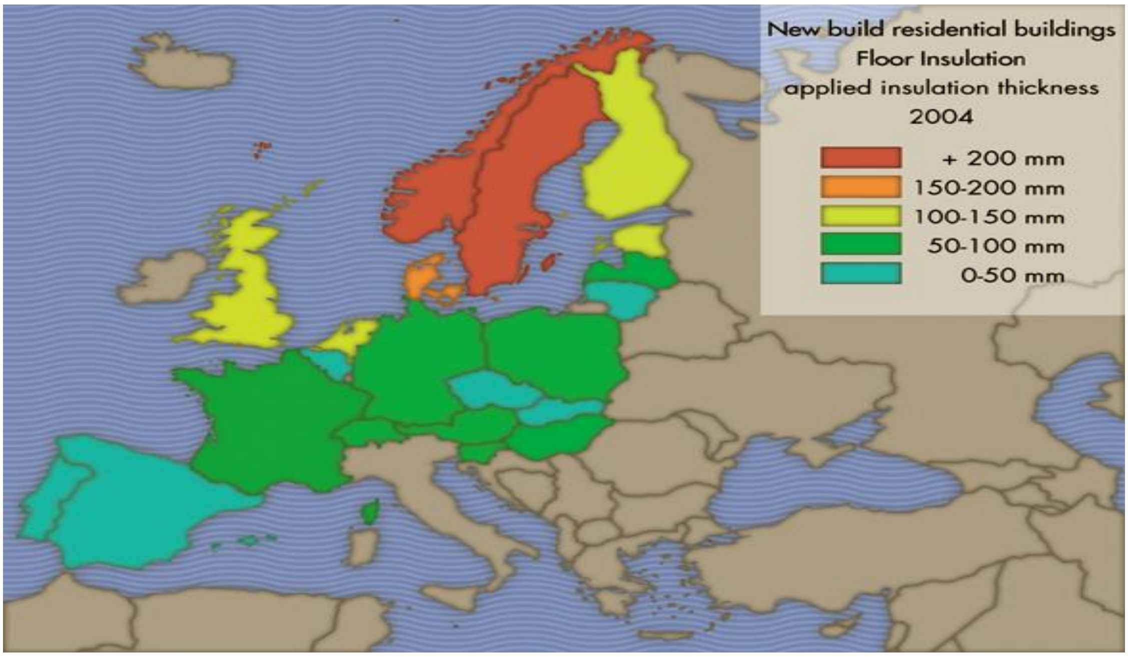


Figure 5.19: Map of EU of Floor Insulation Applied Insulation Thickness.

5.2.3 Roof Construction Applied Thermal Resistance in Insulation

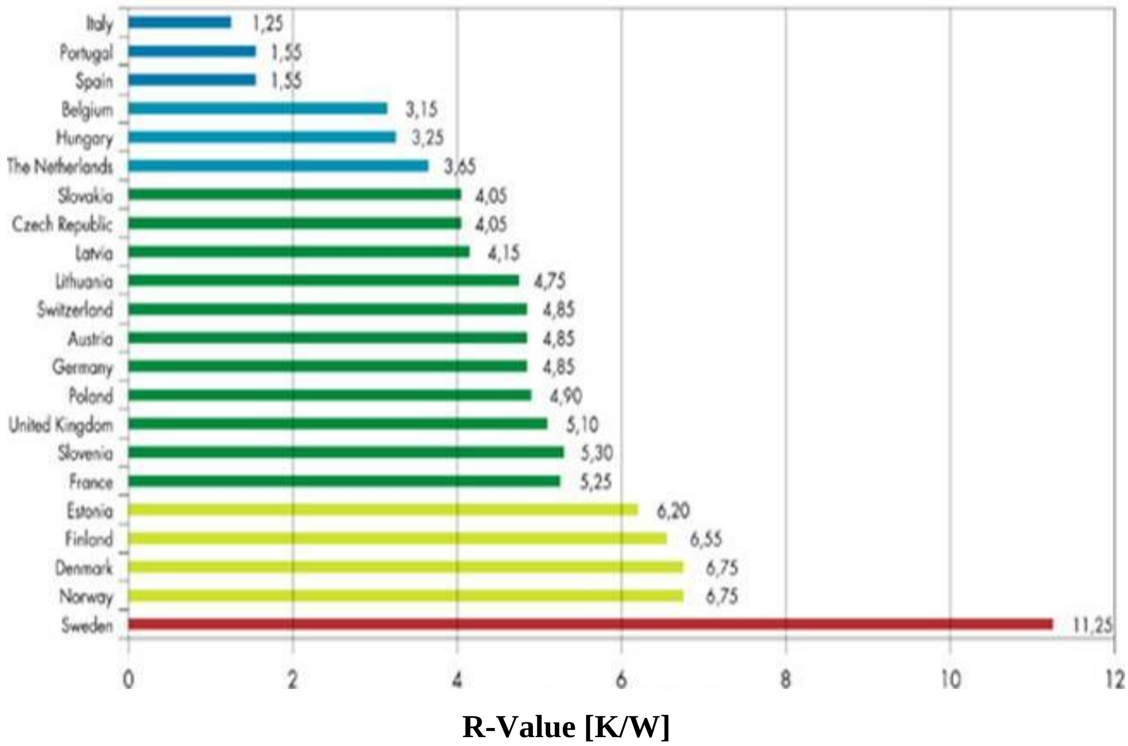


Figure 5.20: Roof Construction Applied Thermal Resistance in Insulation.

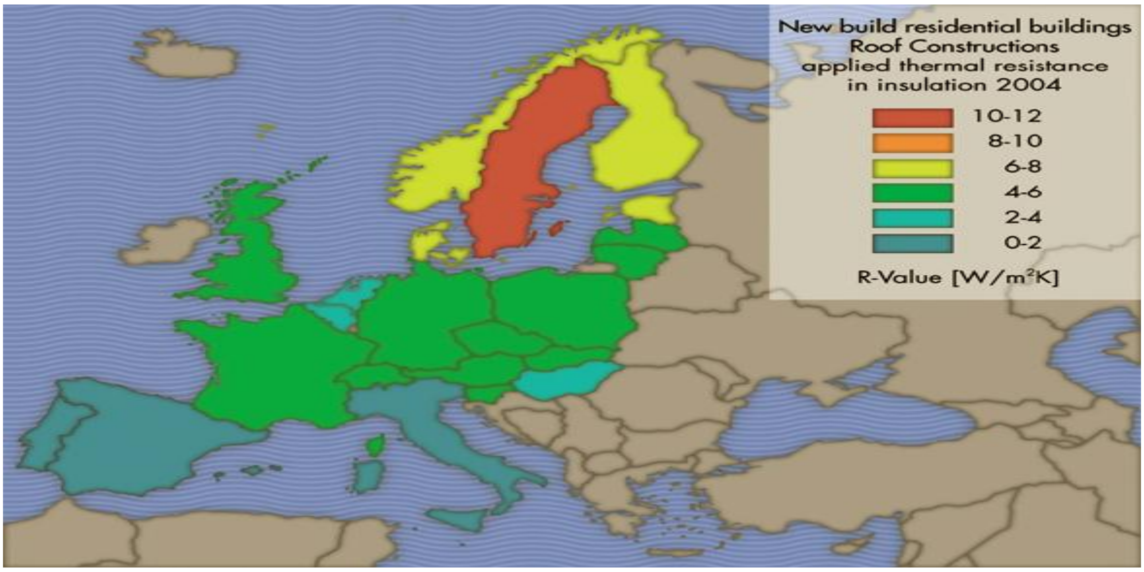


Figure 5.21: Map of EU of Roof Construction Applied Thermal Resistance in Insulation.

5.2.4 Roof Constructions Applied Insulation Thickness

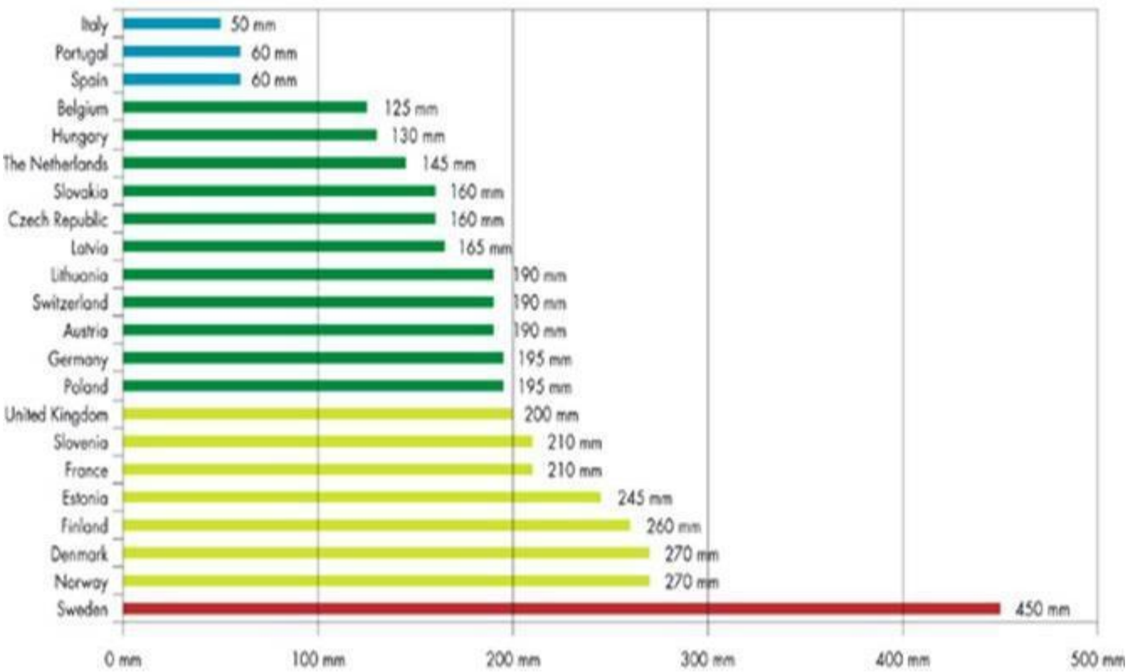


Figure 5.22: Roof Constructions Applied Insulation Thickness.

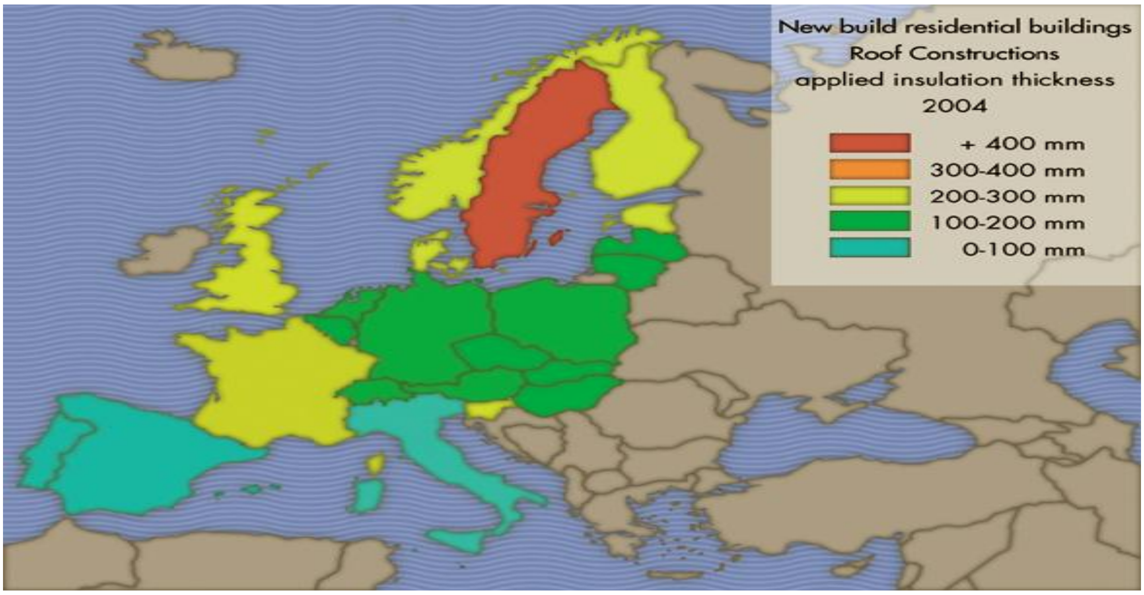
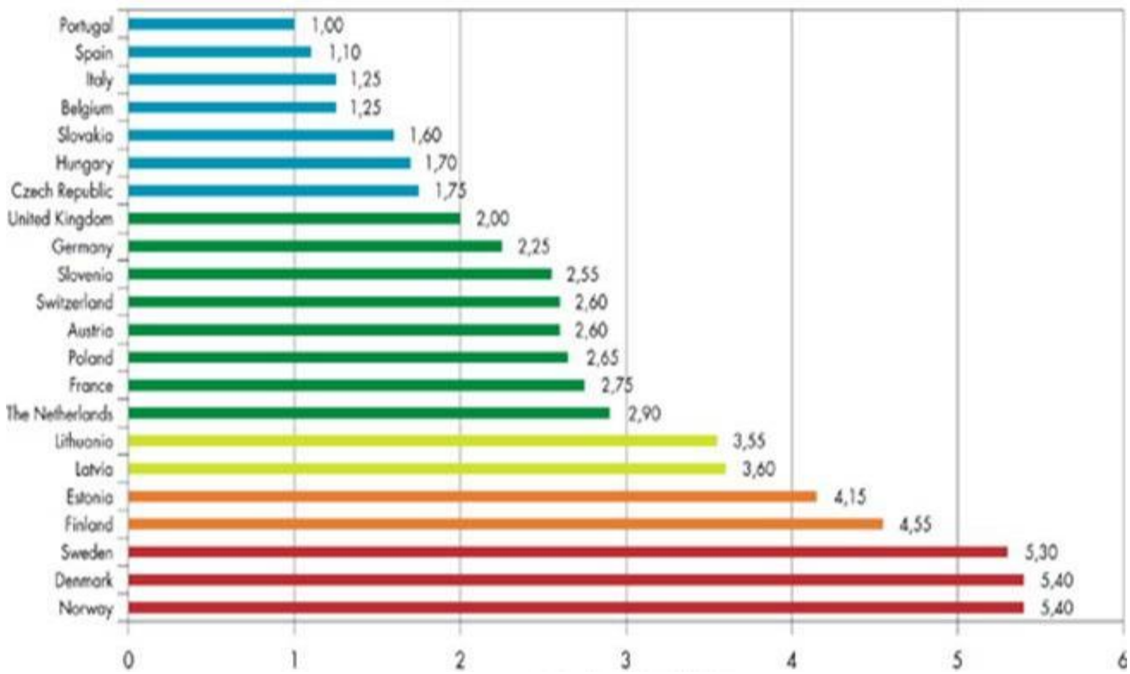


Figure 5.23: Map of EU of Roof Constructions Applied Insulation Thickness.

5.2.5 Wall Constructions Applied Thermal Resistance in Insulation



R-Value [K/W]

Figure 5.24: Wall Constructions Applied Thermal Resistance in Insulation.

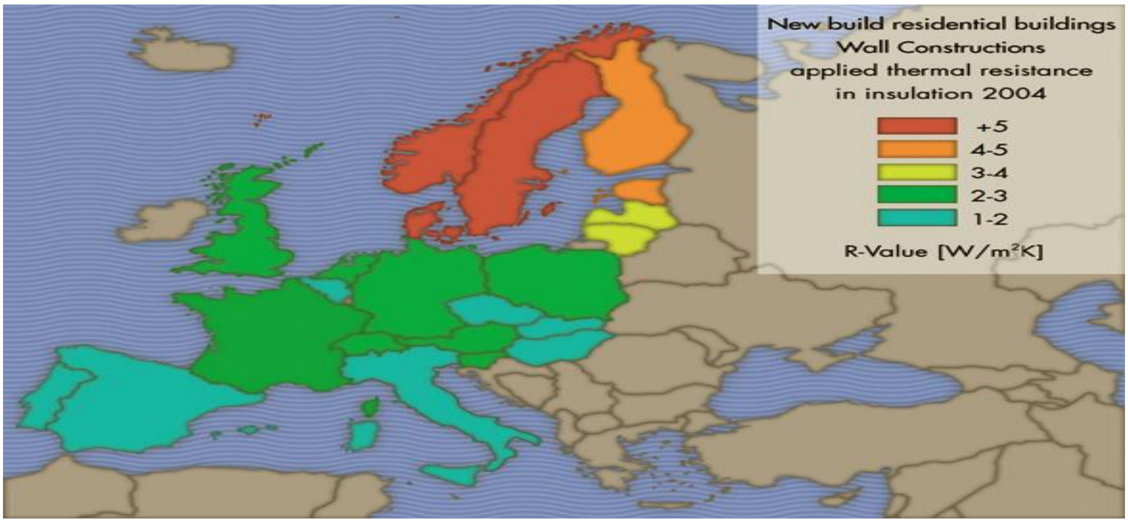


Figure 5.25: Map of EU of Wall Constructions Applied Thermal Resistance in Insulation.

5.2.6 Wall Constructions Applied Insulation Thickness

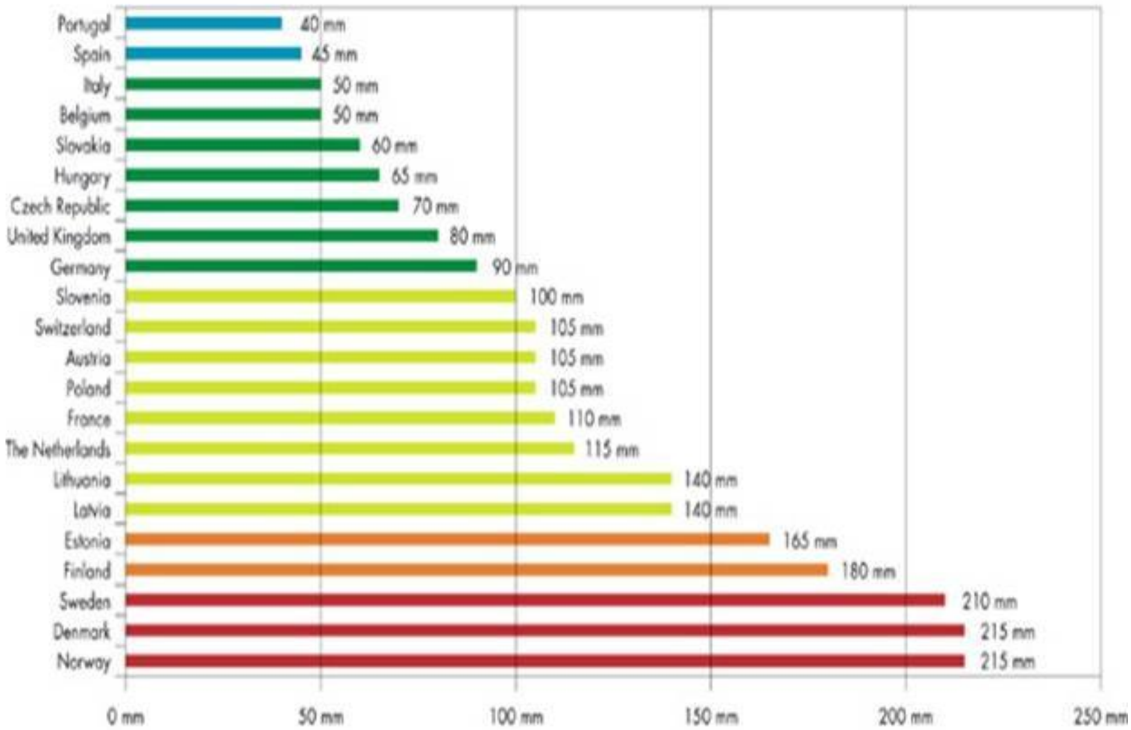


Figure 5.26: Wall Constructions Applied Insulation Thickness.

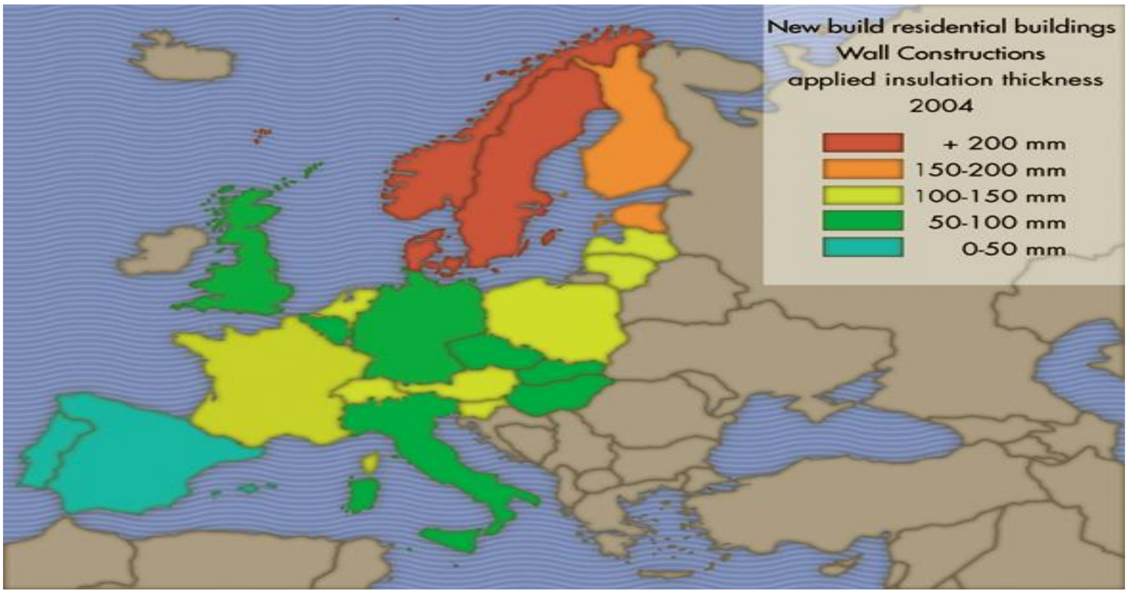


Figure 5.27: Map of EU of Wall Constructions Applied Insulation Thickness [5].

5.3 Building Code of EU Commission for Thermal Insulation

Result from Investigation by the EU Commission

Recently the EU commission published a very interesting investigation about a suggested implementation of a common building code for Europe. The suggestion is to use the Danish building code as a model. It is a very good initiative and it has been long overdue. They have some very unique experiences of the whole issue, since they studied and worked with it for more than 40 years now. Their experiences are also unique in that sense.

Around 50 years ago, Sweden implemented a building standard for thermal insulation in buildings. Norway (not an EU member) followed quite close and Denmark more or less adopted the same standard around more than 15 years later. Denmark has stayed with this building code, with some minor modifications. At the end of the 70's, Sweden did major changes in its building code to include more insulation, but also very important prescriptions concerning surface temperatures and perceived temperature.

The EU commission has in several ways mapped the energy consumption in Europe and has some excellent data that describes the situation. Year 2000 the over all use of energy within the common market was distributed according to the chart in Figure 5.28.

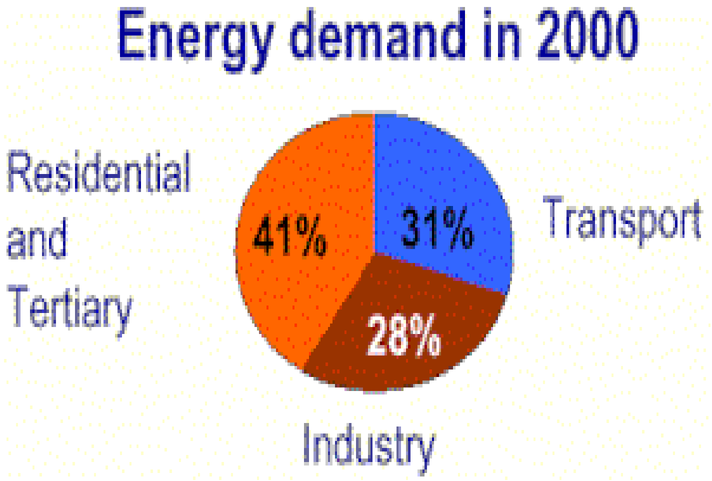


Figure 5.28: The Over All Use of Energy within the Common Market.

The distribution of energy use in buildings, are described in the two charts of Figure 5.29 and Figure 5.30.

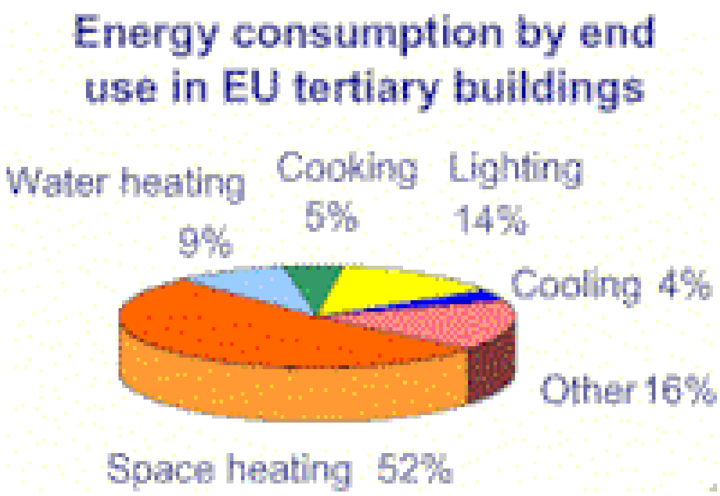


Figure 5.29: Energy Consumption by End Use in EU Tertiary Buildings.

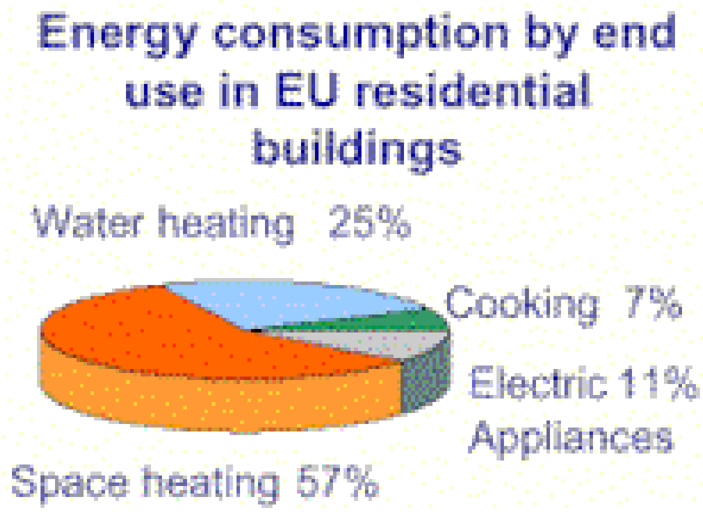


Figure 5.30: Energy Consumption by End Use in EU Residential Buildings.

From this, the EU commission looked at the annual use of energy in the member countries per cubic meter of building space and calculated (with climate corrections) the effect that the Danish building code would have on each member country. The result is shown in the chart of Figure 5.31.

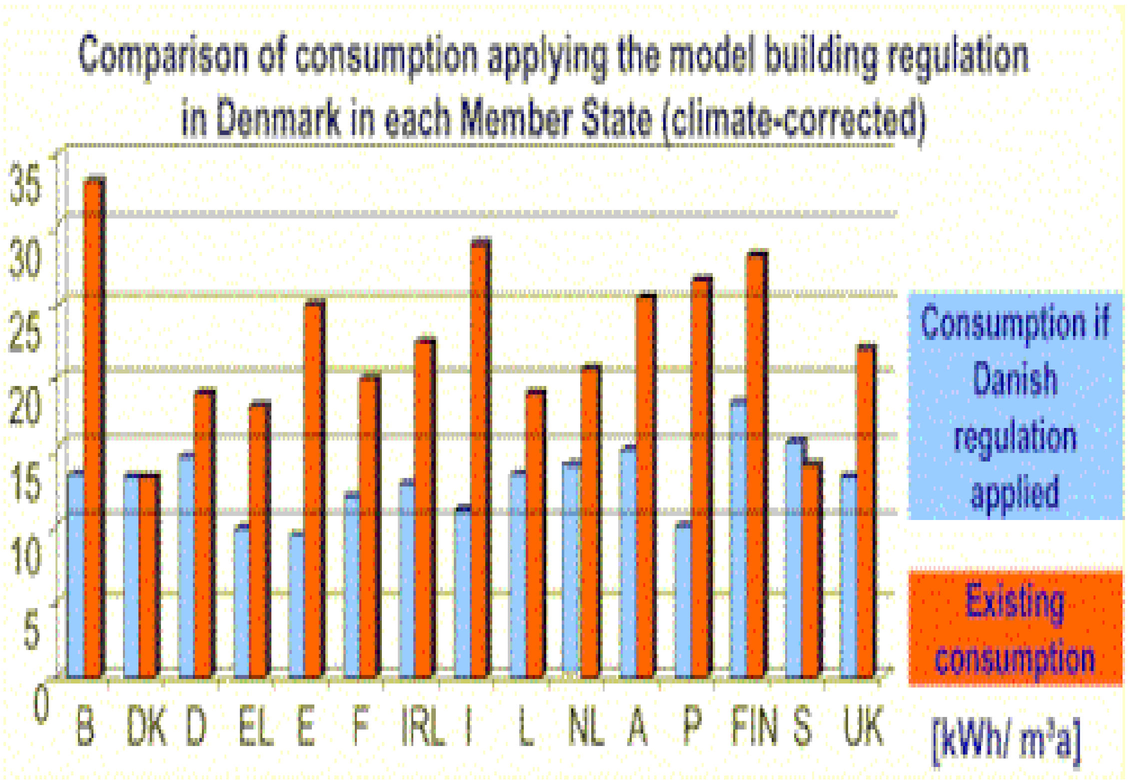


Figure 5.31: Comparison of Consumption Applying the Model Building Regulation in EU.

They find the investigation extremely useful and the suggestion very well meant. In their opinion, the suggestions of these building codes have all necessary merits and should be implemented as soon as possible. They are however not recipes for a solution on how to avoid any major future energy crises. For the current EU members, it will not even provide a relief. It will take more of fast and forceful measures to do so. For this, they need to analyze the data further, to see what can be done. Based on their knowledge and the experiences from the early implementation of thermal insulation in building codes, they will in the following try to add their view on the data. They will also try to explain why Sweden is the only country that would use more energy, if the suggestion was implemented there [44, 5].

6. BUILDING INSULATION IN NORTH CYPRUS

Most modern houses in North Cyprus are not well constructed from the point of view of the environment. Enormous amounts of energy are needlessly wasted in both summer and winter, through cheap and simple construction. The cost of improving this would be small, if the necessary measures were taken at the time of construction. Modifying existing houses would be more expensive. Of course, the drama is a result of the fact that no heating or air conditioning is required for most of the year, but is required for short periods. The use of water on the other hand is also poorly managed in many houses. Again, conservation and recycling water would be cheap if this were foreseen at the time of construction.

6.1 General Information about Construction Components in North Cyprus

Walls

Most houses are constructed with a reinforced concrete skeleton to provide protection against earthquakes. The outside walls are mostly filled in with terracotta bricks of U value with 1.5 w/m^2 k air gaps. Both the inside and outside surfaces are rendered with cement "plastering", to provide a finish suitable for painting. There is no additional insulation.

Roofs

The roofs are mainly flat concrete. There are also inclined concrete roof with terracotta tiles laid on top and flat roofs with terracotta tiles on wooden structure. There is a water proof layer but generally no insulation at all.

Doors

Outside doors are often in MDF and fit badly, allowing air to circulate. In most cases, the front doors open directly into the living room, without a porch or an intermediate hallway. This means that, every time the door is opened in winter, heat escapes and, in summer, heat enters, increasing the load on heating and air conditioning.

Windows

The case of windows is even worse. Semi-reflective double glazing is fairly standard and should be effective. The problem is that the frames and surrounds are in aluminum profiles, which are excellent heat conductors. In the case of sliding double windows and doors, there is a gap of several millimeters between the two window frames. This is "closed" off by a thin brush or rubber flap, allowing an important exchange of air with the outside. This is particularly noticeable in winter when there is a strong wind blowing: cold draughts are inevitable. It would be possible to have wooden-framed casement windows and doors, but the maintenance in the climate would be difficult and expensive. All wood used for construction is imported and expensive and not necessarily of the best quality. There could be considerable shrinkage in the hot, dry summers and expansion in the cool, wet winters. An annual painting would be necessary. The solution out of this dilemma is the use of PVC windows which have increase usage within the last 5 years.

6.2 A Detailed Study on Houses in Northern Cyprus

A questionnaire of 17 questions was prepared and tested among 231 participants living permanently in North Cyprus. Questions and answers can be seen in Appendix A. The discussion on the results can be found in the following section

6.2.1 Distribution of Participants

Figure 6.1 shows the distribution of participants according to the region of North Cyprus.

Choice Regions	Results	Percentages
a- Lefkosa	106	46%
b- Gazimağusa	42	18%
c- Girne	46	20%
d- Güzelyurt	37	16%
e- Iskele	0	0%
	231	

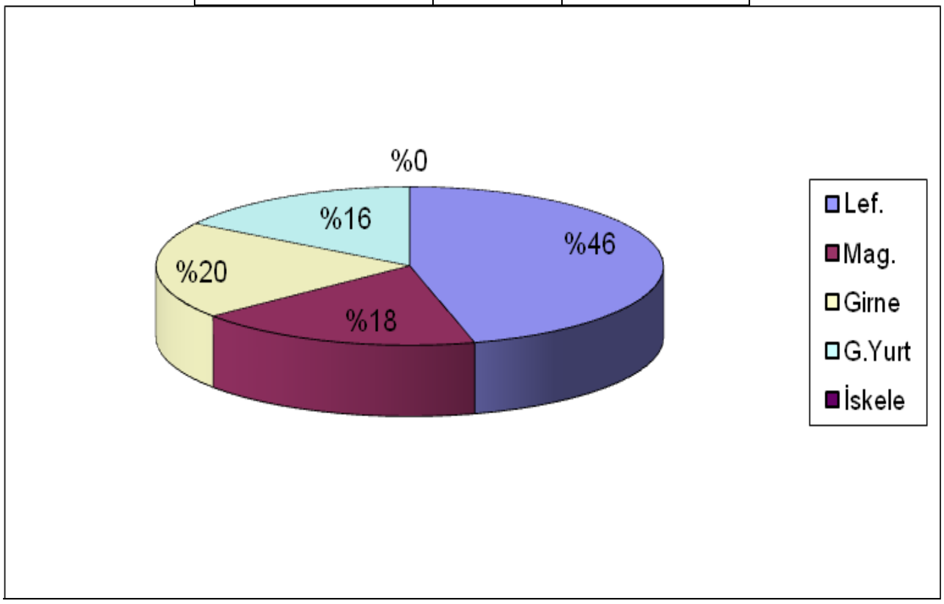


Figure 6.1: Distribution of Participants.

According to TRNC Pry-Ministry Governmental Office of Planning – Population and House Census, 2006 [37] the total population is 265,100 people. The distribution of regions with their percentages and e percentages of the questionnaire can be seen in table 6.1

Table 6.1: Companion of Population Distribution.

Total Population	265100		
	Population	% of population	% of questionnaire
Lefkoşa	85,579	32.3	46
Gazimağusa	64269	24.2	18
Girne	62,158	23.5	20
Güzelyurt	31,116	11.8	16

İskele	21978	8.3	0

When the result of questionnaire and actual population distribution is compared Girne has a good agreement. However, Lefkoşa, Gazimağusa, Cüzelyurt, and İskele have some differences deviations. Deviations can be decreased by collecting more data over the island.

Most of the people in North Cyprus live in Lefkoşa, and Lefkoşa is the area which has worst weather condition, colder in winter and hotter in summer. Therefore, the climate conditions of Lefkoşa can be considered during the analyses in this thesis.

6.2.2 Number of People Living per House

The number of people living in a house can be seen in Figure 6.2. In 231 houses 810 people live. The average of people living in a house is 3.5 in North Cyprus. See Table 6.2.

No. of People	No. of house	No. of people living	people per house %
a- 1	4	4	2
b- 2	32	64	14
c- 3	64	192	28
d- 4	105	420	45
e- >5	26	130	11
	231	810	

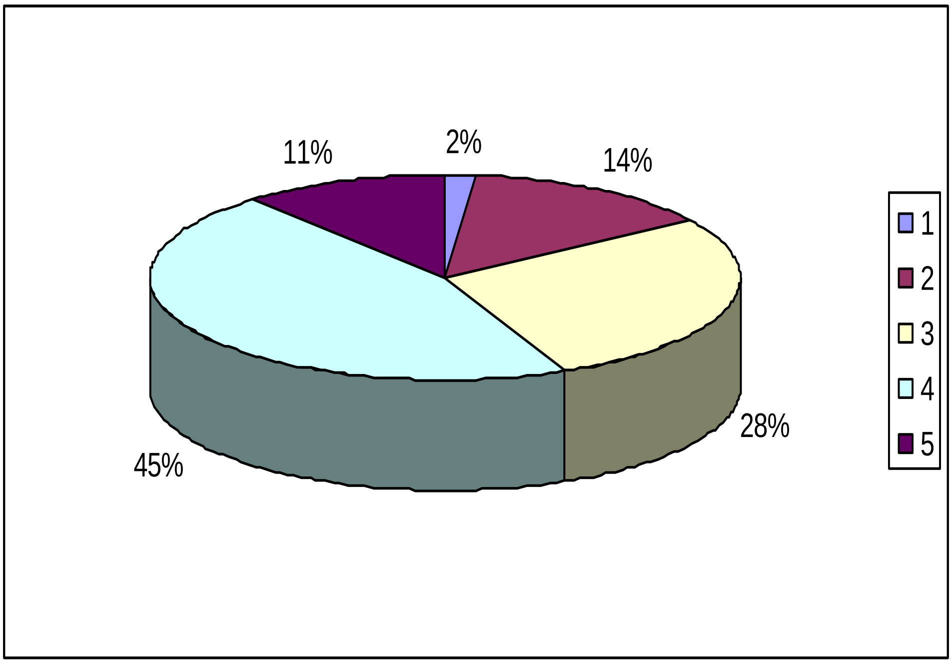


Figure 6.2: Distribution of People per House.

Table 6.2: Average Living People per House in North Cyprus.

No. of people	No. of house considered	No. of people living in considered house	Average living per house %
1	4	4	2
2	32	64	14
3	64	192	28
4	105	420	45
5>	26	130	11
	231	810	3,5

Since the population of North Cyprus is 265,100, the number of active houses in use can be calculated by dividing this number by average people living in a house which is 3.5, it is calculated as 75,477 houses or approximately can be taken as 75,000 houses.

According to TRNC-Pry-Ministry Governmental Office of Planning – Population and House Census, 2006 [37], the average living people in a house 3.17 and the total number of houses are 72,624, which is in a good agreement.

6.2.3 Type of Houses

Figure 6.3 shows the distribution of type of houses in North Cyprus, namely detached, semi-detached and flats. The results of TRNC-Pry-Ministry Governmental Office of Planning – Population and House Census, 2006 [37] for detached houses is (51.7% [37]), which is very close to the results of the questionnaire. However, semi-detached (23.8%) and flats (22.4% [37]) results deviate considerably. The deviation of results will be discussed in details in section 6.5.

Type of house	No. of Houses	Type of houses %
a- Detached	121	53
b- Semi-Detached	12	5
c- Flat	98	42
	231	

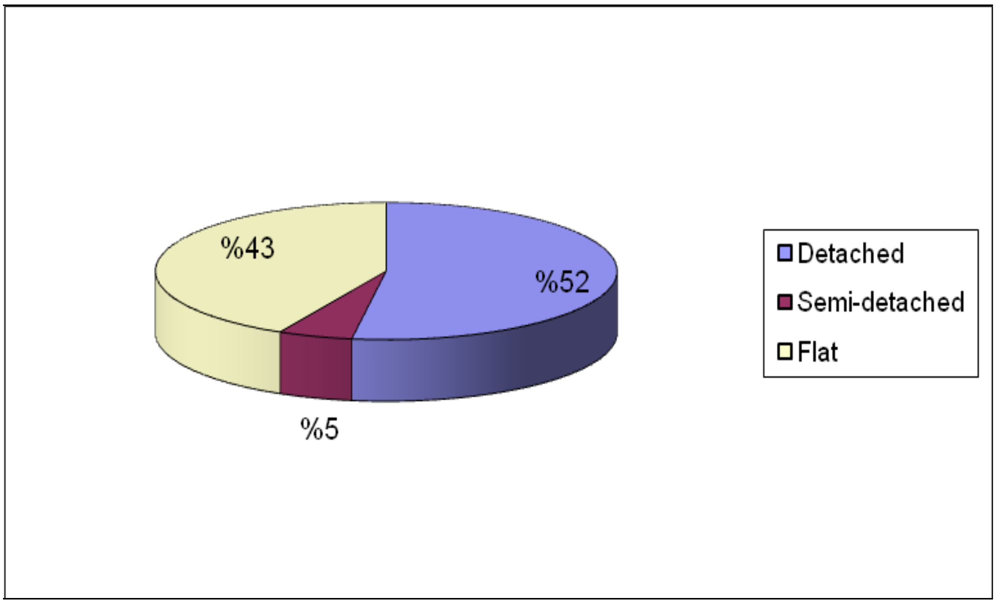


Figure 6.3: Type of Houses.

6.2.4 Age of Houses

To see the changes in properties of houses a question was asked on the age of the house and Figure 6.4 presents the results. (31%) of houses have age more than 20 years, meaning they were built before or within 10 years after the war in 1974.

Although in recent years, there is a tremendous increase in house building, the questionnaire gave only 10% for house age 0-5 years. This shows that new houses are not in active use but are sold for profit in future.

Age of Houses	No. of houses	Houses %
a- 0-5	24	10
b- 5-10	48	21
c- 10-20	88	38
d- >20	71	31
	231	

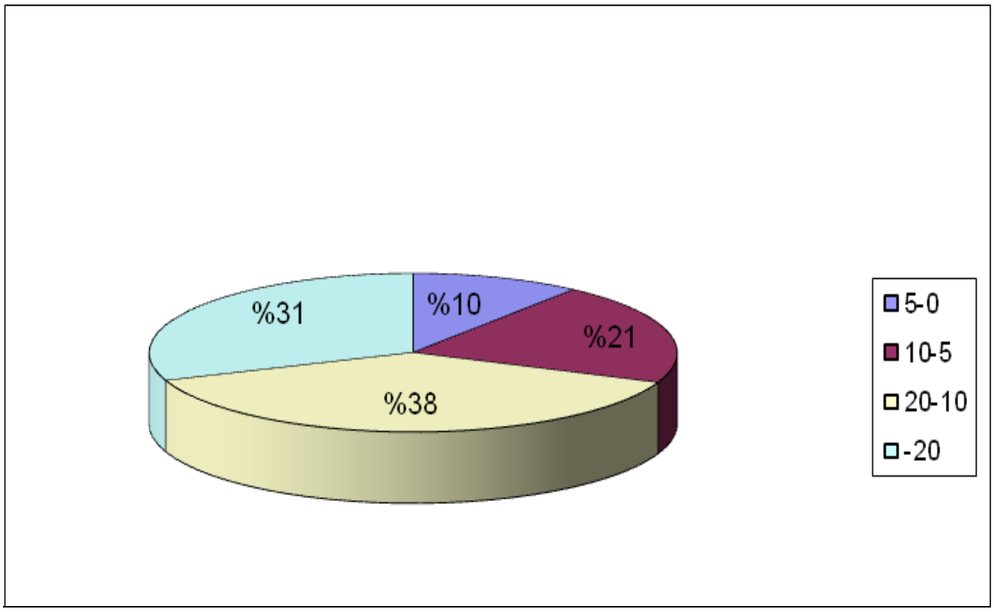


Figure 6.4 Distribution of Age of Houses.

6.2.5 Size of Houses

Figure 6.5 shows questionnaire results on the size of houses in North Cyprus. Most of houses have an area between 100 m^2 – 200 m^2 which is 82%. According to the architecture plans examined the average size of houses in North Cyprus are 135.2 m^2 for detached, 129.9 m^2 for semi-detached, and 139.8 m^2 for flats. (See section 6.5)

Size of houses	No. of houses	Percentages of size houses %
a- less than 100 m^2	25	11
b- 100 m^2 – 200 m^2	189	82
c- larger than 200 m^2	17	7
Total	231	

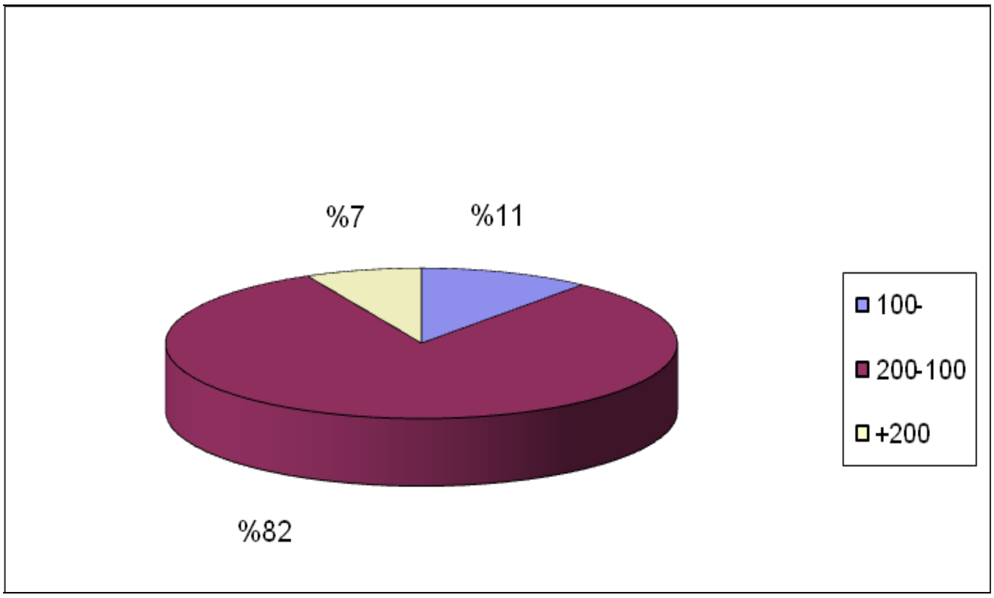


Figure 6.5: Size of Houses.

6.2.6 Construction Materials for Walls

Figure 6.6 shows the distribution of the construction material for walls, Most of houses in North Cyprus are constructed from terracotta bricks (92%). Construction properties may be better for terracotta bricks but it should be insulated in order to decrease the heat loss through wall.

Construction Materials	No. of Houses	Houses %
a- Brick	211	92
b- Concrete	19	8
c- Bimms	1	0
	231	

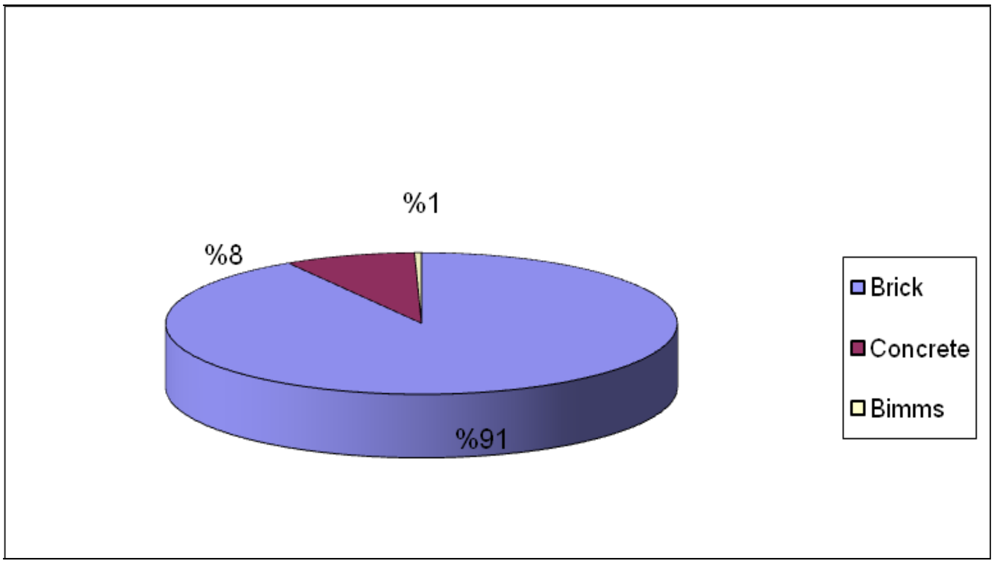


Figure 6.6: Construction Materials for Walls.

Table 6.3 shows the usage of building materials for wall according to the age of houses, terracotta bricks is the most often used one as building material over years. Having better insulation properties, ytong (CB) and bimms (CB) find little use. Moreover, the percent of usage is still decreasing by time.

Table 6.3: Usage of Building Materials for Wall According to the Age of Houses.

Age of Houses	Terracotta bricks		Ytong (CB)		Bimms (CB)		No. of houses
0-5	24	96%	1	4%	0	0%	25
5 – 10	43	91%	4	9%	0	0%	47
10 - 20	85	96%	4	4%	0	0%	89
20>	59	84%	10	14%	1	1%	70
Total	211		19		1		231
Total percentages		91%		8%		0%	99%

* CB: Concrete Blocks

6.2.7 Distribution of Wall Insulation

Figure 6.7 shows distribution of wall insulation, Most of the walls of houses in North Cyprus are poorly insulated or not insulated at all. Only 7% of the houses (most of them new) have insulation on walls by some means. That is why there is a high heat loss through walls of houses and need to be considered to save energy.

Insulation Material	No. of Houses	Houses %
a- Glass Wool	3	1
b- Polyurethane	8	3
c- Air Gap	4	2
d- No Insulation	216	94
Total	231	

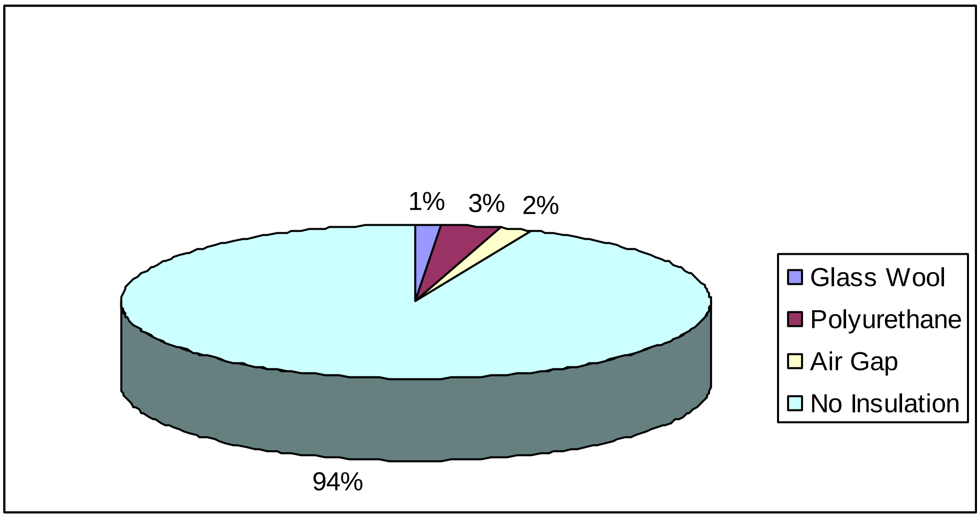


Figure 6.7: Distribution of Wall Insulation.

Table 6.4 shows change of wall insulation over time. The use of Polyurethane as an insulating material, remaining the same glass wool and air cavity slightly increasing. Walls with no insulation are decreasing slightly. There is a little improved on wall insulation. However, it is still far away from being satisfactory.

Table 6.4: Change of Wall Insulation According to the Age of Houses.

Age of Houses	Glass Wool		Polyurethane		Air Gap		No Insulation		No. of houses
0-5	1	4,3%	1	4,3%	1	4,3%	20	87,0%	23
5 - 10	0	0,0%	3	6,3%	0	0,0%	45	93,8%	48
10 - 20	1	1,1%	0	0,0%	2	2,3%	84	96,6%	87
20>	1	1,5%	4	5,9%	1	1,5%	62	91,2%	68
Total	3		8		4		211		226

6.2.8 Distribution of Insulation Direction in Walls

Figure 6.8 shows the distribution of direction of walls insulated in North Cyprus. Since, only 7% of houses are insulated in North Cyprus, and people do not know the importance of insulation this question does not give trustable results, and will not be not considered.

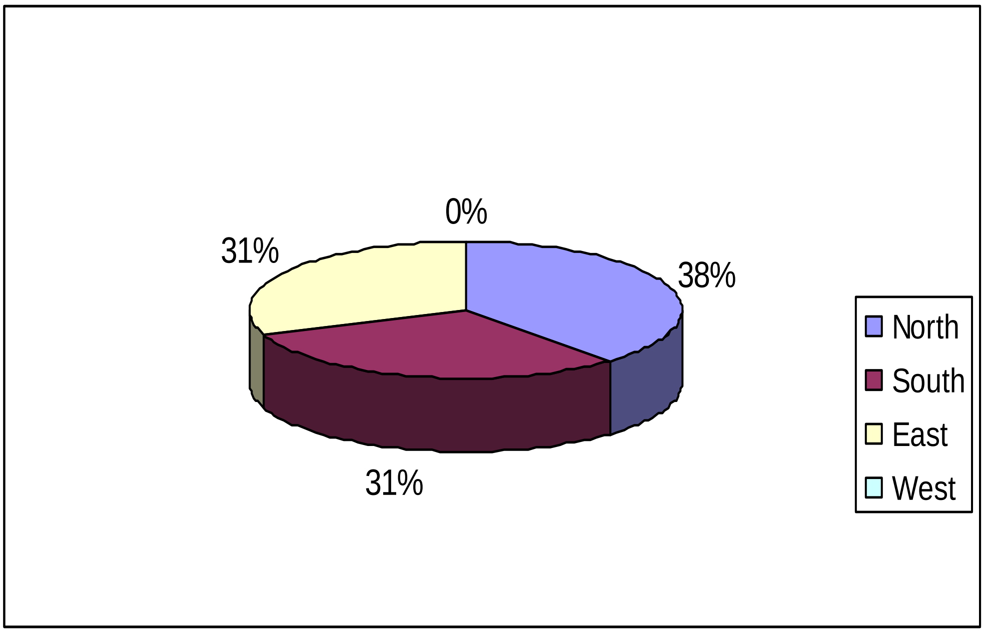


Figure 6.8: Distribution of Insulation Direction of Walls.

6.2.9 Window Materials

Figure 6.9 shows the distribution of window materials and the percentages of using those materials in North Cyprus, most of windows are aluminum (78%), Wood and PVC windows are more expensive, that is why they are not used much. PVC windows are the best in preventing infiltration of air. Wood and aluminum needs extra effort to improve infiltration properties. However, only 5 % of houses use PVC windows.

Window Materials	No. of houses	window materials %
a- Wood	39	17
b- Aluminum	181	78
c- PVC	11	5
Total	231	

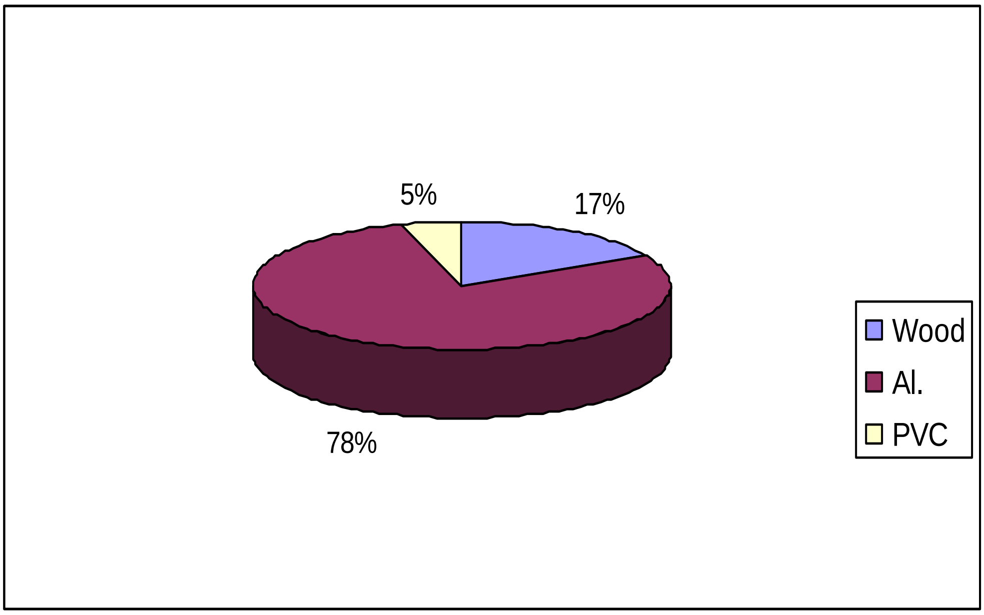


Figure 6.9: Distributions of Window Materials.

Table 6.5 shows the change of window materials with time. In the past the only alternative window was wooden window, after the production of aluminum and PVC, especially aluminum started to be used because of its lower price and no maintenance. In the last 5 years PVC windows find application in the building sector and a sudden increase in usage was observed, while aluminum usage decreased. In the last 10 years almost non wooden window was used, because of high price and change in technology.

Table 6.5: Changes of Window Materials According to the Age of Houses.

Age of Houses	Wood		Aluminum		PVC		Total
0-5	0	0%	18	75%	6	25%	24
5 – 10	0	0%	45	96%	2	4%	47
10 - 20	8	9%	79	89%	2	2%	89
>20	31	44%	39	55%	1	1%	71

6.2.10 Window Glazing

Figure 6.10 shows the distribution of single and double glazed windows in North Cyprus. Even though it is much better to use double glazed window in order to decrease the heat loss through windows, it can be seen from the results of questionnaire that most of windows in North Cyprus are single glazed (85%). There is an increase of usage of double glazed windows through time. Table 6.6 shows this increase in the usage of double glazed windows. For the last 5 years the usage of single and double glazing was more or less the same.

Window Glazing	No. of houses	Glazing %
SG	196	85
DG	35	15
Total	231	

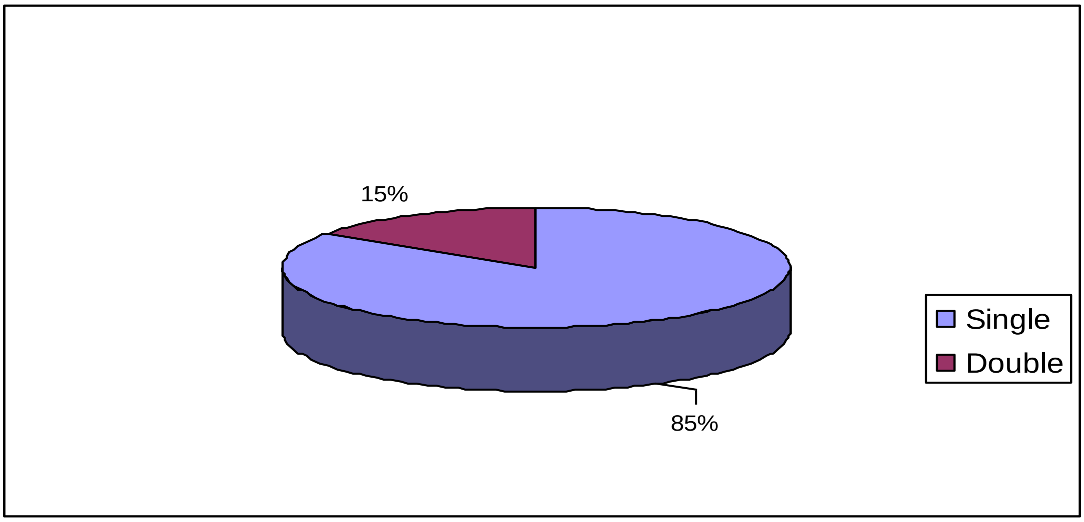


Figure 6.10: Window Glazing.

Table 6.6: Increases of Usage Double Glazing Window with Time.

Age of houses	Single Glazing		Double Glazing		Total
0-5	13	54%	11	46%	24
5 – 10	39	81%	9	19%	48
10 - 20	81	92%	7	8%	88
>20	63	89%	8	11%	71
Total	196		35		231

6.2.11 Roof Types

Figure 6.11 shows the distribution of roof types in North Cyprus. Most of roofs in North Cyprus are flat concrete roof which is 64% according to the questionnaire, but concrete and roof tiles are the most often used roof types in European Countries. Since it is more effective in insulation. However, in North Cyprus it is only 18%.

Roof Type	No .of houses	Roof type %
a- Flat Concrete Roof	150	46
b- Inclined Concrete Roof & Roof Tiles	20	9
c- Flat Concrete roof plus roof tiles on wooden roof structure	41	18
d- Others	20	9
Total	231	

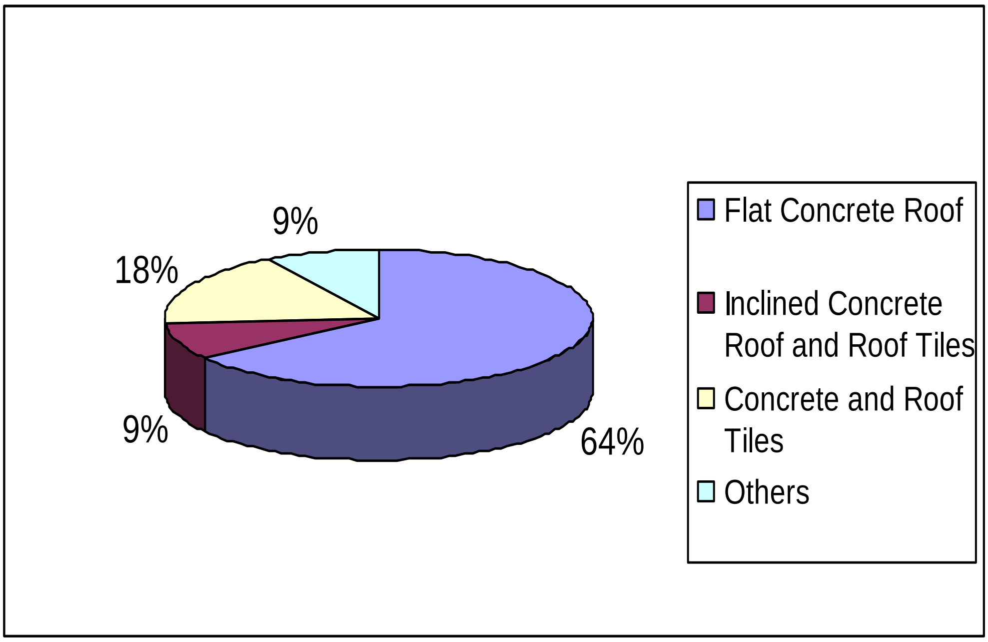


Figure 6.11 Roof Type.

Table 6.7 shows the change of roof types by time, there are increased and decreased usages by time. However, in the last 5 years there is an increase in inclined C. R. and R. T. can be observed.

Table 6.7: Changes of Roof Types by Time.

Age of House	Flat concrete roof		Inclined C. R. and R. T.		Flat C. R. + R. T. on wooden Str.		Others		Total
0-5	14	58,3%	5	20,8%	3	12,5%	2	8,3%	24
5 – 10	29	60,4%	0	0,0%	15	31,3%	4	8,3%	48
10 - 20	65	73,9%	6	6,8%	15	17,0%	2	2,3%	88
>20	42	59,2%	9	12,7%	8	11,3%	12	16,9%	71
Total	150		20		41		20		231

6.2.12 Roof Insulation

Figure 6.12 shows the distribution of roof insulation. The roofs in North Cyprus are not insulated, even though the largest amount of energy loss in a building is from roof. To be able to decrease the heat loss, the roofs of the houses must be insulated as well as walls, and floors.

Roof Insulation	No. of houses	Roof Insulation %
a- Glass Wool	10	4
b- Polyurethane	16	7
c- No Insulation	201	89
Total	227	

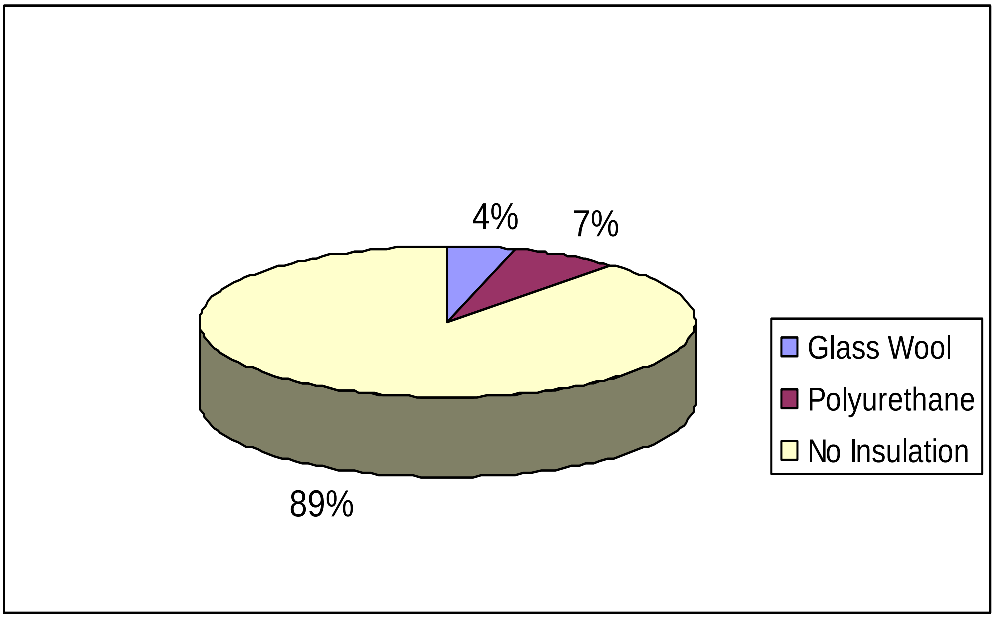


Figure 6.12: Roof Insulation.

Table 6.8 shows the change of roof insulation by time, it can be seen that roof insulation is getting better by time but need much more improvement.

Table 6.8: Changes of Roof Insulation According to the Age of Houses.

Age of house	Glass wool		Polyurethane		No insulation		Total
0-5	3	13%	1	4%	20	83%	24
5 – 10	1	2%	5	11%	40	87%	46
10 - 20	3	3%	3	3%	82	93%	88
20>	3	4%	7	10%	62	86%	72
Total	10		16		204		230

6.2.13 Heating Types

Figure 6.13 shows the main heating types usage in North Cyprus. Since North Cyprus has a warm climate, central heating is not used much. Local heating using heaters and air conditioners is preferred with a percentage of 98%. According to TRNC-Pry ministry Governmental Office of Planning – Population and House Census, 2006 [37] the percentages of usage of central heating is 2.61% and the rest is for heaters and air conditions.

Heaters using LPG, electric, and kerosene have COP of 1. It is better to use air conditioning units. Since recently, air conditioning units have COP at least 3. To save energy air conditioning units seems to be the most efficient ones. However, there is a serious electricity shortage in North Cyprus and this problem needs an urgent solution.

Heating Type	No. of houses	Heating Type %
a- Central Heating	5	2
b- Heater	122	53
c- Air Conditions	103	45
Total	230	

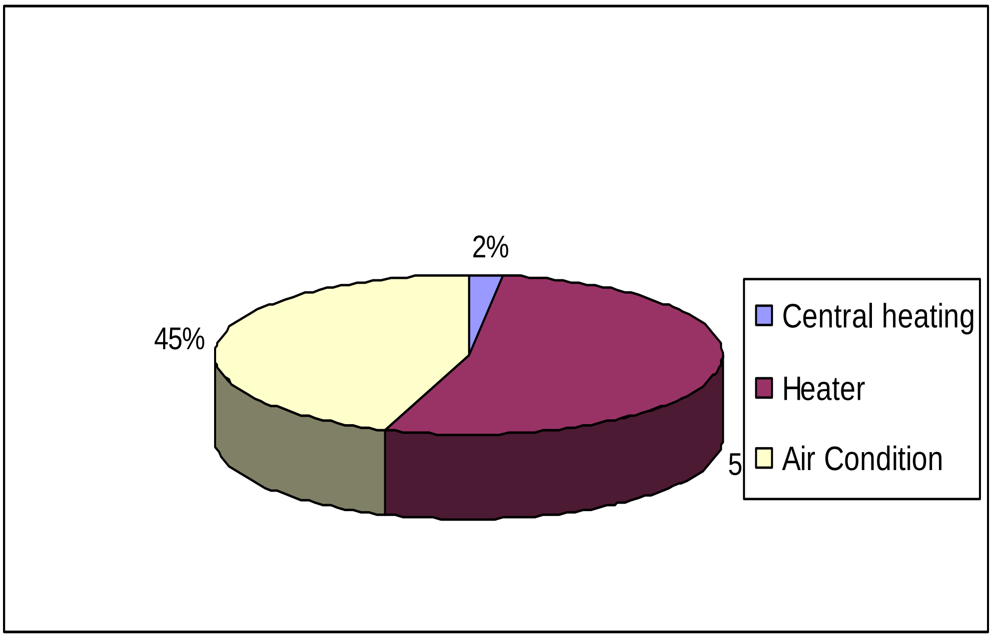


Figure 6.13: Distribution of Heating Types in Houses.

Table 6.9 shows the changes of the main heating types by time. Most of houses in North Cyprus are using air conditioners with an increase in percentage, expect for the last 5 years.

Table 6.9: Changes of the Main Heating Types According to the Age of Houses.

Age of house	Central Heating		Heater		Air Conditions		Total
0-5	4	17%	9	38%	11	46%	24
5 – 10	0	0%	20	42%	28	58%	48
10 - 20	1	1%	47	53%	40	45%	88
20>	0	0%	47	66%	24	34%	71
Total	5		123		103		231

6.2.14 Energy Source for Heating

Figure 6.14 shows the main energy source for heating in houses of North Cyprus. Most of people in North Cyprus use electricity (66%) in stead of other energy source for heating. It is better to use electricity because of global warm, but North Cyprus is in short of electric energy which needs a solution.

Energy Sources for heating	No. of houses Considered	Energy sources for heating %
a- Wood	3	1
b- Electric	152	66
c- Gas LPG	64	28
d- Kerosene	9	4
e- Diesel	3	1
Total	231	

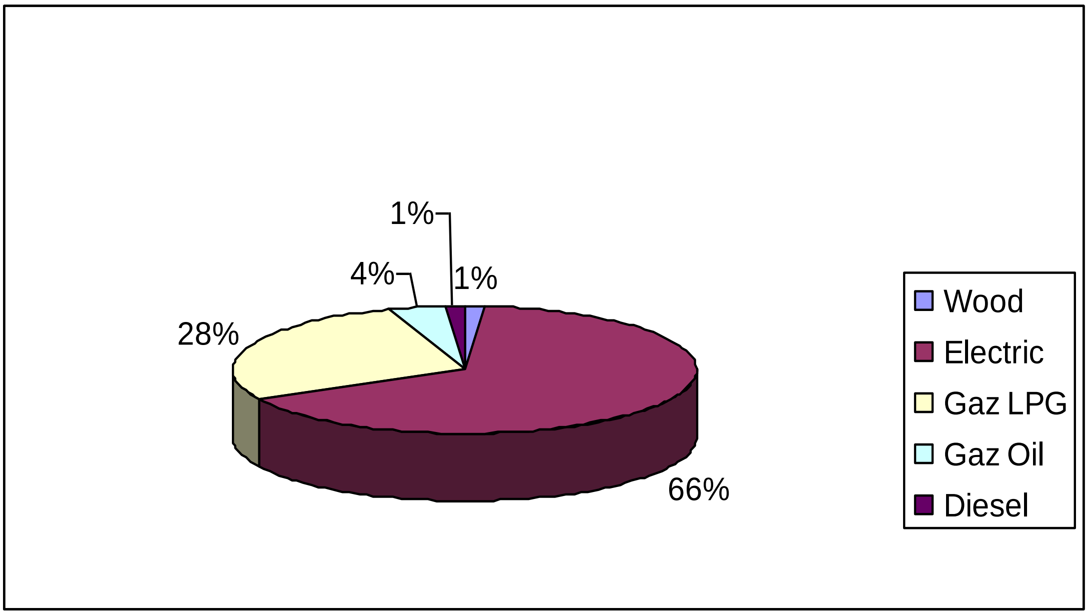


Figure 6.14: Distributions of Energy Sources for Heating.

Table 6.10 shows the usage of main heating types and energy sources. As it can be seen the houses using air conditioners as the main source heating is 98%. However, 2% also uses LPG, besides electricity as heaters. Many heater users' main source of energy is LPG with 52% and electricity as 33%.

When Figures 6.13 and 6.14 are compared central heating uses diesel and LPG with 1% each over energy sources. Reaming 27% of LPG is used by heaters. 45% of electricity is used for AC and remains 21% is used for heaters summing up to 66%.

Table 6.10: Energy Sources of Heating Types.

Heating Types	Wood		Electric		Gas LPG		Kerosene		Diesel		Total
CH	0	0%	2	67%	1	33%	0	0%	0	0%	3
H	3	3%	49	43%	59	52%	0	0%	2	2%	113
AC	0	0%	101	98%	2	2%	0	0%	0	0%	103
Total	3		152		62		0		2		219

- CH: Central Heating, H: Heater, AC: Air Conditions.

6.2.15 Electric Bills

Figure 6.15 shows the distribution of electric bills per month in North Cyprus. As an average most of bills come between the amounts of 100-300 YTL monthly, which is still high. To be able to decrease this amount the houses must be insulated.

100-300 YTL per month is the common amount with 63%. If it is considered that 66% of the main source of energy is electricity, the results verify each other.

Electric bill	No. of houses	Electric bill %
a- 0-100 YTL	79	34
b- 100-300 YTL	144	63
c- 300-600 YTL	8	3
d- 600> YTL	0	0
Total	231	

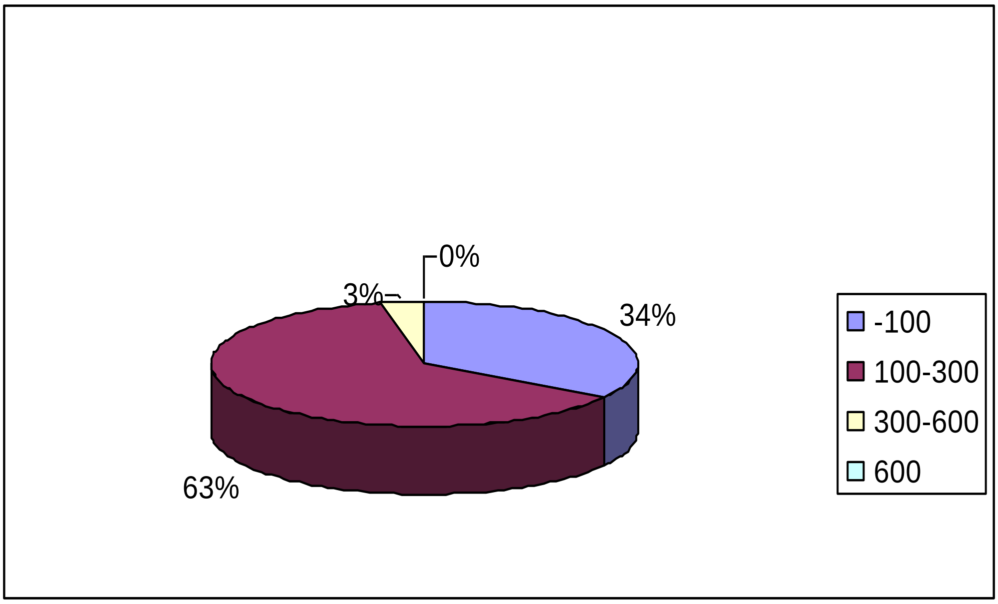


Figure 6.15: Distribution of Electric Bills.

6.2.16 Bills of Heating Expect Electricity

Figure 6.16 shows the distributions of monthly amount of money spend in winter for energy source except electricity. However, during the questionnaire it was observed that the participant miss understand, this question and therefore it will not be considered.

Bills for Other Source of Energy	No. of houses	% No. of Houses
a- 0-100 YTL	118	51
b- 100-300 YTL	109	47
c- 300-600 YTL	4	2
d- 600> YTL	0	0
Total	231	

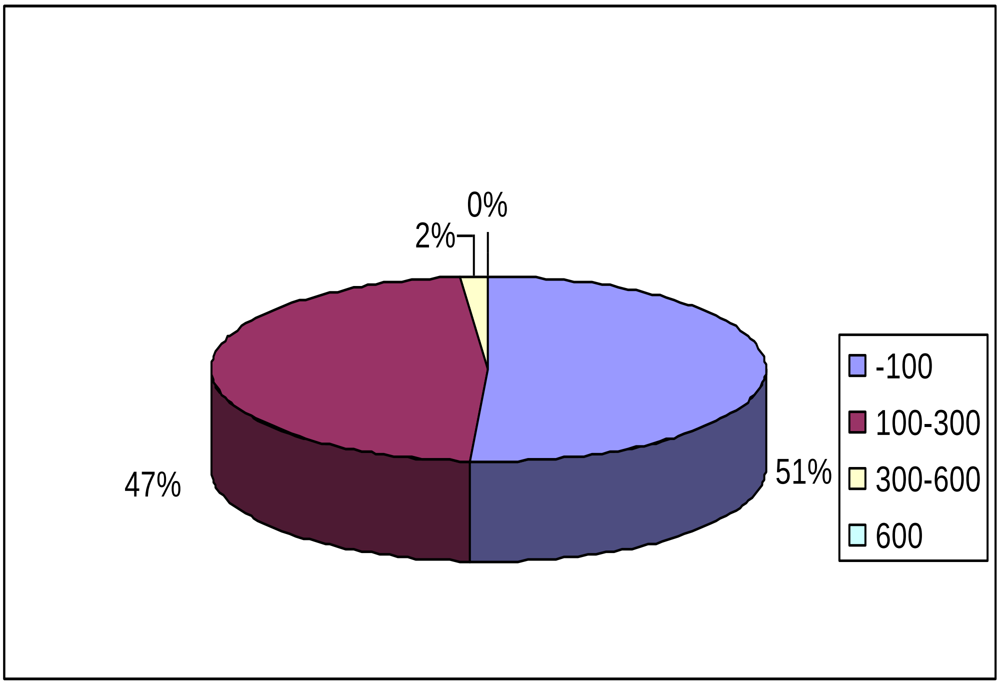


Figure 6.16: Distribution of Electric Bills in Winter.

6.2.17 Air Conditioners in Houses

Figure 6.17 shows the distribution of air conditioners usage in houses of North Cyprus, 31% has no air conditioners at all while 1 or 2 air conditioners are most common.

No. of Air Conditions	No. of houses	air conditioners %
a- None	71	31
b- 1	49	21
c- 2	55	24
d- 3	38	16
e- 3>	18	8
Total	231	

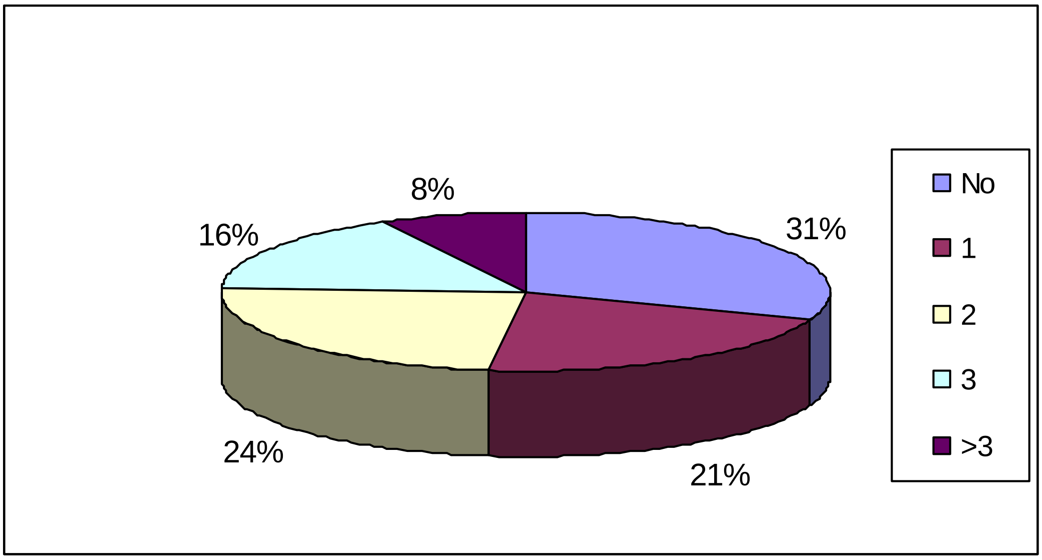


Figure 6.17: Distribution of Air Conditioners in North Cyprus.

6.3 Distribution of Houses According to Building Components

Tables 6.11, 6.12, and 6.13 show the distribution of houses according to wall materials, roof insulation, window frame material, and glazing in consideration with the results of questionnaire, for detached, semi-detached and flats respectively.

The results obtained will be used in calculating the heat loss from an average house in North Cyprus, which will include the characteristics properties of the house and construction types.

Table 6.11: Distribution of Detached Houses According to Wall Materials, Wall Insulation, Roof Insulation, Window Materials and Glazing.

Case No.	House Type	Wall Material	Wall Insulation	Roof Insulation	Windows Material	Glazing Type	# of Houses	%
1	D	TB	NI	NI	Wood	SG	23	10.088%
2	D	TB	NI	NI	Wood	DG	0	0.000%
3	D	TB	NI	NI	AL	SG	63	27.632%
4	D	TB	NI	NI	AL	DG	12	5.263%
5	D	TB	NI	NI	PVC	SG	0	0.000%
6	D	TB	NI	NI	PVC	DG	2	0.877%
7	D	CB	NI	NI	Wood	SG	3	1.316%
8	D	CB	NI	NI	Wood	DG	0	0.000%
9	D	CB	NI	NI	AL	SG	7	3.070%
10	D	CB	NI	NI	AL	DG	1	0.439%

11	D	CB	NI	NI	PVC	SG	0	0.000%

Table 6.11: Distribution of Detached Houses According to Wall Materials, Wall Insulation, Roof Insulation, Window Materials and Glazing (continued).

12	D	CB	NI	NI	PVC	DG	0	0.000%
13	D	TB	NI	I	Wood	SG	0	0.000%
14	D	TB	NI	I	Wood	DG	0	0.000%
15	D	TB	NI	I	AL	SG	2	0.877%
16	D	TB	NI	I	AL	DG	0	0.000%
17	D	TB	NI	I	PVC	SG	0	0.000%
18	D	TB	NI	I	PVC	DG	0	0.000%
19	D	CB	NI	I	Wood	SG	0	0.000%
20	D	CB	NI	I	Wood	DG	0	0.000%
21	D	CB	NI	I	AL	SG	0	0.000%
22	D	CB	NI	I	AL	DG	0	0.000%
23	D	CB	NI	I	PVC	SG	0	0.000%
24	D	CB	NI	I	PVC	DG	0	0.000%
25	D	TB	I	NI	Wood	SG	1	0.439%
26	D	TB	I	NI	Wood	DG	0	0.000%
27	D	TB	I	NI	AL	SG	1	0.439%
28	D	TB	I	NI	AL	DG	0	0.000%
29	D	TB	I	NI	PVC	SG	0	0.000%
30	D	TB	I	NI	PVC	DG	0	0.000%
31	D	CB	I	NI	Wood	SG	0	0.000%
32	D	CB	I	NI	Wood	DG	0	0.000%
33	D	CB	I	NI	AL	SG	0	0.000%
34	D	CB	I	NI	AL	DG	0	0.000%
35	D	CB	I	NI	PVC	SG	0	0.000%
36	D	CB	I	NI	PVC	DG	0	0.000%
37	D	TB	I	I	Wood	SG	0	0.000%
38	D	TB	I	I	Wood	DG	2	0.877%
39	D	TB	I	I	AL	SG	0	0.000%
40	D	TB	I	I	AL	DG	1	0.439%
41	D	TB	I	I	PVC	SG	0	0.000%
42	D	TB	I	I	PVC	DG	1	0.439%
43	D	CB	I	I	Wood	SG	0	0.000%
44	D	CB	I	I	Wood	DG	0	0.000%
45	D	CB	I	I	AL	SG	0	0.000%
46	D	CB	I	I	AL	DG	1	0.439%
47	D	CB	I	I	PVC	SG	0	0.000%
48	D	CB	I	I	PVC	DG	0	0.000%
Total						120		

- D: Detached, TB: Terracotta Brick, CB: Concrete Block, NI: Non Insulated, I: Isolated, AL: Aluminum, SG: Single Glazing, DG: Double Glazing.

Table 6.12: Distribution of Semi-detached Houses According to Wall Materials, Wall Insulation, Roof Insulation, Window Materials and Glazing.

Case No.	House Type	Wall Material	Wall Insulation	Roof Insulation	Windows Material	Glazing Type	# of Houses	%
1	SD	TB	NI	NI	Wood	SG	4	1.754%
2	SD	TB	NI	NI	Wood	DG	0	0.000%
3	SD	TB	NI	NI	AL	SG	5	2.193%
4	SD	TB	NI	NI	AL	DG	0	0.000%
5	SD	TB	NI	NI	PVC	SG	0	0.000%
6	SD	TB	NI	NI	PVC	DG	2	0.877%
7	SD	CB	NI	NI	Wood	SG	0	0.000%
8	SD	CB	NI	NI	Wood	DG	0	0.000%
9	SD	CB	NI	NI	AL	SG	0	0.000%
10	SD	CB	NI	NI	AL	DG	0	0.000%
11	SD	CB	NI	NI	PVC	SG	0	0.000%
12	SD	CB	NI	NI	PVC	DG	0	0.000%
13	SD	TB	NI	I	Wood	SG	0	0.000%
14	SD	TB	NI	I	Wood	DG	0	0.000%
15	SD	TB	NI	I	AL	SG	0	0.000%
16	SD	TB	NI	I	AL	DG	0	0.000%
17	SD	TB	NI	I	PVC	SG	0	0.000%
18	SD	TB	NI	I	PVC	DG	0	0.000%
19	SD	CB	NI	I	Wood	SG	0	0.000%
20	SD	CB	NI	I	Wood	DG	0	0.000%
21	SD	CB	NI	I	AL	SG	0	0.000%
22	SD	CB	NI	I	AL	DG	0	0.000%
23	SD	CB	NI	I	PVC	SG	0	0.000%
24	SD	CB	NI	I	PVC	DG	0	0.000%
25	SD	TB	I	NI	Wood	SG	0	0.000%
26	SD	TB	I	NI	Wood	DG	0	0.000%
27	SD	TB	I	NI	AL	SG	0	0.000%
28	SD	TB	I	NI	AL	DG	0	0.000%
29	SD	TB	I	NI	PVC	SG	0	0.000%
30	SD	TB	I	NI	PVC	DG	0	0.000%
31	SD	CB	I	NI	Wood	SG	0	0.000%
32	SD	CB	I	NI	Wood	DG	0	0.000%
33	SD	CB	I	NI	AL	SG	0	0.000%
34	SD	CB	I	NI	AL	DG	0	0.000%
35	SD	CB	I	NI	PVC	SG	0	0.000%
36	SD	CB	I	NI	PVC	DG	0	0.000%
37	SD	TB	I	I	Wood	SG	0	0.000%
38	SD	TB	I	I	Wood	DG	0	0.000%
39	SD	TB	I	I	AL	SG	0	0.000%

40	SD	TB	I	I	AL	DG	0	0.000%
41	SD	TB	I	I	PVC	SG	0	0.000%
42	SD	TB	I	I	PVC	DG	0	0.000%
43	SD	CB	I	I	Wood	SG	0	0.000%
44	SD	CB	I	I	Wood	DG	0	0.000%
45	SD	CB	I	I	AL	SG	0	0.000%

Table 6.12: Distribution of Semi-detached Houses According to Wall Materials, Wall Insulation, Roof Insulation, Window Materials and Glazing (continued).

46	SD	CB	I	I	AL	DG	0	0.000%
47	SD	CB	I	I	PVC	SG	0	0.000%
48	SD	CB	I	I	PVC	DG	1	0.439%
Total						12		

- SD: Semi-Detached

Table 6.13: Distribution of Flats According to Wall Materials, Wall Insulation, Roof Insulation, Window Materials and Glazing.

Case No.	House Type	Wall Material	Wall Insulation	Roof Insulation	Windows Material	Glazing Type	# of Houses	%
1	F	TB	NI	NI	Wood	SG	3	1.316%
2	F	TB	NI	NI	Wood	DG	0	0.000%
3	F	TB	NI	NI	AL	SG	67	29.38%
4	F	TB	NI	NI	AL	DG	6	2.632%
5	F	TB	NI	NI	PVC	SG	0	0.000%
6	F	TB	NI	NI	PVC	DG	0	0.000%
7	F	CB	NI	NI	Wood	SG	2	0.877%
8	F	CB	NI	NI	Wood	DG	0	0.000%
9	F	CB	NI	NI	AL	SG	4	1.754%
10	F	CB	NI	NI	AL	DG	1	0.439%
11	F	CB	NI	NI	PVC	SG	0	0.000%
12	F	CB	NI	NI	PVC	DG	0	0.000%
13	F	TB	NI	I	Wood	SG	0	0.000%
14	F	TB	NI	I	Wood	DG	0	0.000%
15	F	TB	NI	I	AL	SG	3	1.316%
16	F	TB	NI	I	AL	DG	2	0.877%
17	F	TB	NI	I	PVC	SG	0	0.000%
18	F	TB	NI	I	PVC	DG	1	0.439%
19	F	CB	NI	I	Wood	SG	0	0.000%
20	F	CB	NI	I	Wood	DG	0	0.000%
21	F	CB	NI	I	AL	SG	1	0.439%
22	F	CB	NI	I	AL	DG	0	0.000%
23	F	CB	NI	I	PVC	SG	1	0.439%
24	F	CB	NI	I	PVC	DG	0	0.000%
25	F	TB	I	NI	Wood	SG	0	0.000%
26	F	TB	I	NI	Wood	DG	0	0.000%
27	F	TB	I	NI	AL	SG	0	0.000%
28	F	TB	I	NI	AL	DG	0	0.000%
29	F	TB	I	NI	PVC	SG	0	0.000%
30	F	TB	I	NI	PVC	DG	0	0.000%
31	F	CB	I	NI	Wood	SG	0	0.000%
32	F	CB	I	NI	Wood	DG	0	0.000%

33	F	CB	I	NI	AL	SG	0	0.000%
34	F	CB	I	NI	AL	DG	0	0.000%
35	F	CB	I	NI	PVC	SG	0	0.000%
36	F	CB	I	NI	PVC	DG	0	0.000%
37	F	TB	I	I	Wood	SG	0	0.000%
38	F	TB	I	I	Wood	DG	0	0.000%

Table 6.13: Distribution of Flats According to Wall Materials, Wall Insulation, Roof Insulation, Window Materials and Glazing (continued).

39	F	TB	I	I	AL	SG	2	0.877%
40	F	TB	I	I	AL	DG	0	0.000%
41	F	TB	I	I	PVC	SG	1	0.439%
42	F	TB	I	I	PVC	DG	1	0.439%
43	F	CB	I	I	Wood	SG	0	0.000%
44	F	CB	I	I	Wood	DG	0	0.000%
45	F	CB	I	I	AL	SG	0	0.000%
46	F	CB	I	I	AL	DG	0	0.000%
47	F	CB	I	I	PVC	SG	1	0.439%
48	F	CB	I	I	PVC	DG	0	0.000%
Total							96	

- F: Flat

6.4 Determination of Total Heat Loss Transfer Coefficient of Building Components

6.4.1 Walls

6.4.1.1 Concrete Blocks:

Plaster-Concrete Blocks-Plaster (P-CB-P)

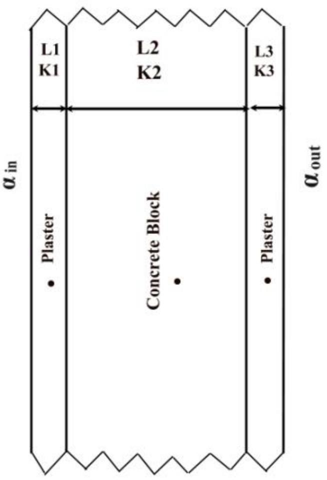


Figure 6.18: A wall without Insulation Using Concrete Blocks Material Construction

U_{CB} = 0.18 W/m.K　　L_1= 3 cm

$U_{Plaster}$ = 0.3 W/m.K　　L_2= 19 cm

α_{in} = 7 W/m^{2}K　　　　　　　　L_3= 3 cm
α_{out} = 20 W/m^{2}K

Using equation $Q = U.A.\Delta T$ and data above, the overall heat transfer coefficient is 0.690 W/m^2.

6.4.1.2 Terracotta Brick:

Plaster-Terracotta Bricks-Plaster (P-TB-P).

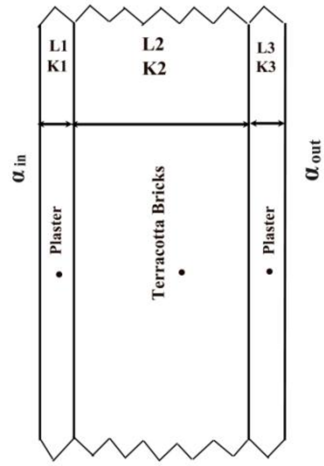


Figure 6.19: A wall without Insulation Using a Terracotta Bricks Material Construction

U_{TB}: 0.7 W/m.K　　　　　　L_1= 3 cm
$U_{Plaster}$: 0.3 W/m.K　　　　L_2= 19 cm
α_{in}: 7 W/m^{2}K　　　　　　L_3= 3 cm
$\alpha_{out:}$ 20 W/m^{2}K

Using equation [1] and data above, the overall heat transfer coefficient is 1.5053 W/m^{2}K.

6.4.1.3 Concrete Blocks with Insulation:

Plaster-Concrete Blocks-Insulation-Concrete Blocks-Plaster or Plaster-Insulation-Concrete Blocks-Plaster.

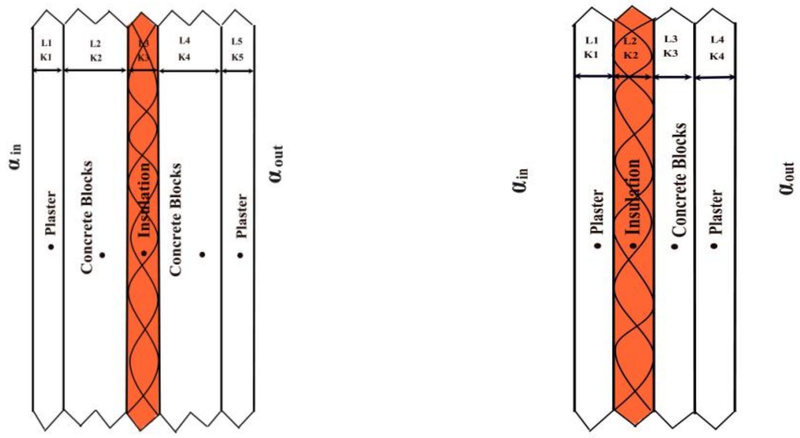


Figure 6.20: A wall with Insulation Using Concrete Blocks Material Construction.

L_1= 3cm	U_{CB}= 0.18 W/m.K	L_1= 3cm
L_2= 10cm	$U_{Plaster}$= 0.3 W/m.K	L_2= 5cm
L_3= 5cm	U_{Pinso}= 0.04 W/m.K	L_3= 19cm
L_4= 10cm	α_{in}= 7 W/m^{2}K	L_4= 3cm
L_5= 3cm	α_{out}= 20 W/m^{2}K	

Using equation [10] for the two types above gives the same overall heat transfer coefficient Value which is (0.37) W/m^{2}K.

6.4.1.4 Terracotta Bricks with Insulation:

Plaster-Terracotta Bricks-Insulation-Terracotta Bricks-Plaster or Plaster-Insulation-Terracotta Bricks-Plaster

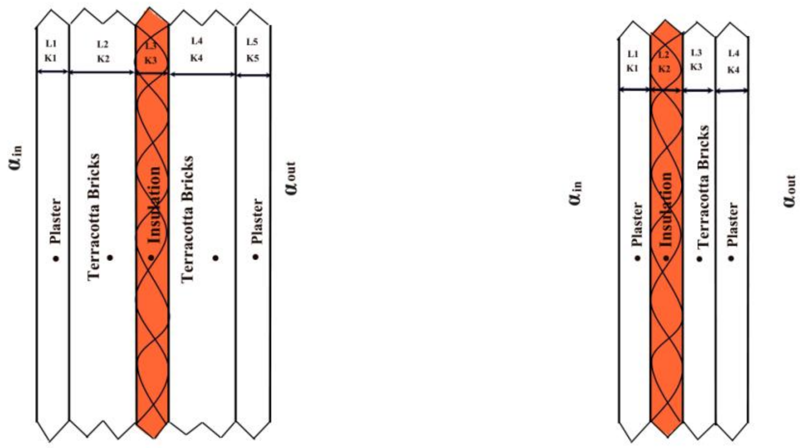


Figure 6.21: A wall with Insulation Using Terracotta Bricks Material Construction.

L_1= 3cm	U_{TB}= 0.7 W/m.K	L_1= 3cm
L_2= 10cm	$U_{Plaster}$= 0.3 W/m.K	L_2= 5cm
L_3= 5cm	U_{Pinso}= 0.04 W/m.K	L_3= 19cm
L_4= 10cm	α_{in}= 7 W/m^{2}K	L_4= 3cm
L_5= 3cm	α_{out}= 20 W/m^{2}K	

Using equation [10] and data above for the two types, the overall heat transfer coefficient is 0.52 W/m^{2}K.

6.4.2 Roofs

6.4.2.1 Concrete Roof with out Insulation (R)

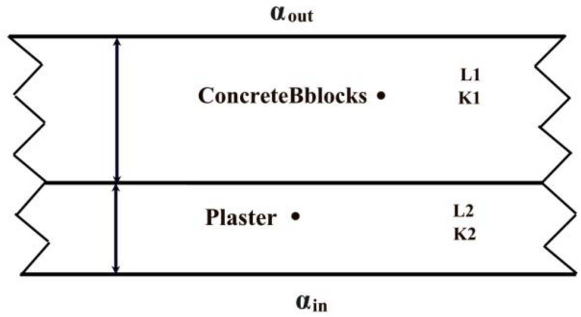


Figure 6.22: Concrete Roof with Out Insulation.

U_{CB}= 1.0 W/m.K
$U_{Plaster}$= 0.3 W/m.K
α_{in}= 7 W/m^{2}K
α_{out} = 20 W/m^{2}K

L_1= 3cm
L_2= 20cm

Using equation [10] and data above, the overall heat transfer coefficient is 2.0325 W/m^{2}K.

6.4.2.2 Concrete Roof with Insulation (RI)

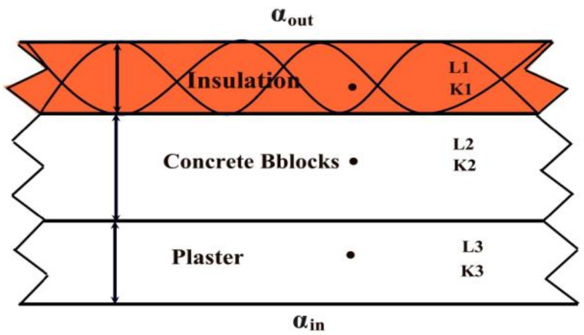


Figure 6.23: Concrete Roof with Insulation.

U_{CB}: 1.0 W/m.K
$U_{Plaster}$: 0.3 W/m.K
k_{Pinso}: 0.04 W/m.K
α_{in}: 7 W/m^{2}K
$\alpha_{out:}$ 20 W/m^{2}K

L1= 3cm
L2= 20cm
L3= 5cm

Using equation [1] and data above, the overall heat transfer coefficient is 0.5740 W/m^{2}K

6.4.3 Floor

6.4.3.1 Concrete Floor with out Insulation (F_r)

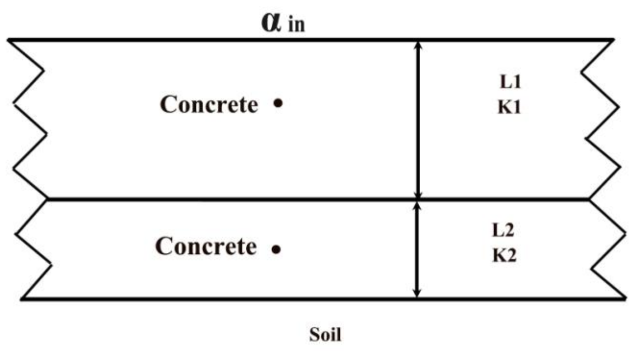


Figure 6.24: Concrete Floor with Out Insulation.

k_{CB}: 1.0 W/m.K L1= 10cm
α_{in}: 7 W/m^{2}K L2= 20cm

Using equation [1] and data above, the overall heat transfer coefficient is 2.26 W/m^{2}K.

6.4.3.2 Concrete Floor with Insulation (F_rI)

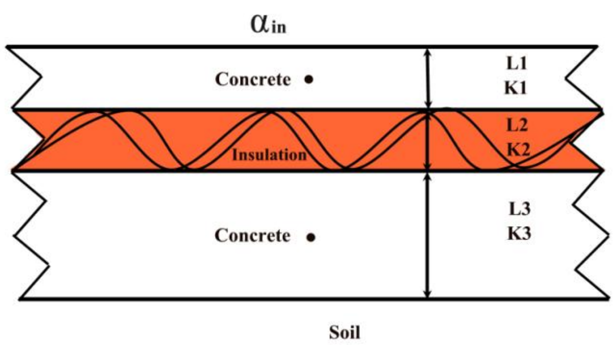


Figure 6.25: Concrete Floor with Insulation.

$k_{Concrete}$: 1.0 W/m.K L1= 10cm
k_{inso}: 0.04 W/m.K L2= 5cm
α_{in}: 7 W/m^{2}K L3= 20cm

Using equation [10] and data above, the overall heat transfer coefficient is 0.59 W/m^{2}K.

Table 6.14: The Total U-Value of Roofs, Floors, Windows and Walls.

Type	**U (w/m^{2}k)**
Roofs (CB)	
Non Insulation	2.03
Insulation	0.57
Floor (CB)	

Non Insulation	2.26
Insulation Type 1	0.59
Windows	
Single Glass	5,59
Double Glass	3.01
Wall (TB)	
Non Insulation	1.5
Insulation	0.52
Wall (CB)	
Non Insulation	0.69
Insulation	0.37

6.5 Determination of Characteristics Properties of Houses in North Cyprus

To investigate the characteristic properties of house types 67 randomly chosen architectural planes were exempted for their net area, wall area, and window area.

Tables 6.15, 6.16, and 6.17 show detached, semi-detached and flats type houses data. According to these data the average net area, wall area, and window area were calculated. The ratio of (wall area / net area), and (window area / net area) can also be seen in Table 6.18.

Table 6.15: House Components of Detached.

No.	Name	Type	Length of walls (m)	Gross Area of walls (m^2)	Area of windows (m^2)	Net Area of Walls (m^2)	Area of House (m^2)
1	Villa (Mehmet Erureten Mımarı)	D	51.3	154.1	27.3	126.8	119.0
2	Villa (e-tipi)	D	46.1	138.5	27.5	110.9	97
3	Villa (hpvize.enson1)	D	64.7	194.3	42.8	151.4	157.6
4	Planlar	D	69.5	208.7	42.9	165.7	217
5	Plan-dwg-lecant	D	69.1	207.5	38.7	168.7	196
6	Plan-kes-gör	D	44.8	134.5	24.2	110.3	49
7	me-ibrahim seren	D	50.7	152.1	41.9	110.2	120
8	Villa (me-kaliikiz)	D	29.4	88.3	13.4	74.9	52
9	Mimari1	D	62.9	188.9	32.3	156.6	194
10	Mimari2	D	51.5	154.7	30.6	124.1	154
11	Murat	D	77.3	231.9	41.8	190.1	272
12	Mımarı Vize	D	52.3	156.9	26.6	130.3	130
13	A kafa Mekanık	D	50.9	152.7	37.3	115.4	114
14	PL	D	49.1	147.5	20.6	126.8	132
15	Nuretın	D	37.1	111.2	27.2	83.9	80
16	Plan2	D	56.8	170.6	42.2	128.4	152
17	Mımarı	D	53.2	159.7	32.3	127.3	190
18	Villa	D	33.9	101.7	20.6	81.0	110
19	Ramın	D	52.1	156.5	32.5	123.9	147
20	Selcan Sermin1	D	44.6	134.0	21.8	112.1	95.6

Table 6.15: House Components of Detached (continued).

21	Senay Onde-mim	D	56	168.0	33.1	134.9	181
22	Yanki	D	50.6	152.0	37.3	114.6	120
23	Ranan	D	75.7	227.3	54.3	172.9	177
24	Plan1	D	48.5	145.7	40.8	104.9	131.5
25	Faıka Kusappı Vıze	D	37.2	111.8	20.6	91.1	82.7
26	k 297-Dr Cenk	D	50.4	151.4	42.4	109.0	124.1
27	c-tipi	D	51	153.1	36.9	116.2	122.5
28	d-tipi	D	46.6	140.1	27.5	112.5	97
29	Planlar2	D	47.5	142.5	36.7	105.7	97
30	Planlar3	D	46.3	138.9	25.2	113.7	116.3
31	Planlar6	D	54.2	162.8	51.8	110.9	114
32	Planlar5	D	54.9	164.9	27.1	137.7	121
33	Savas Plan	D	58.2	174.6	38.9	135.7	114
34	Me-Alman4	D	43.3	129.9	26	103.8	124
35	Almanin Evi	D	63.1	189.3	37.2	152.0	159.2
36	ADNAN M.Z.	D	49.2	147.7	9.5	138.1	138.1
37	t-sel	D	72.2	216.8	37	179.7	209
38	a-tipi	D	47.4	142.3	36.7	105.6	105.5
39	ciddi Planlar	D	43.6	130.8	29.7	101.1	160
				Avg.	**32.7**	**124.6**	**135.2**
					0.24	**0.92**	

Table 6.16: House Components of Semi-Detached.

No.	Name	Type	Length of walls (m)	Gross Area of walls (m^2)	Area of windows (m^2)	Net Area of Walls (m^2)	Area of House (m^2)
1	Aysel Plan	SD	43.6	131.0	18.59	112.5	93
2	Plan	SD	64.5	193.5	37.36	156.1	189
3	ersoy 22 plan	SD	46.8	140.4	14.9	125.4	107
4	eski vize PLANLAR	SD	45.2	135.8	26.3	109.4	123
5	Ozsoy Vize Mımarı	SD	37.8	113.6	14.8	98.8	90
6	Faıka Kusappı Vıze	SD	37.2	111.8	20.6	91.1	83
7	Tülinarch	SD	88	264.0	63.6	200.4	245.5
8	Nedim Alsancak	SD	34	102.0	18.7	83.2	72
				Avg.	**28.1**	**123.5**	**129.9**
					0.21	**0.95**	

Table 6.17: House Components of Flats.

No.	Name	Type	Length of walls (m)	Gross Area of walls (m^2)	Area of windows (m^2)	Net Area of Walls (m^2)	Area of House (m^2)
1	Flat	F	31.1	93.3	24.9	68.4	119.0
2	Apartment (Mine)	F	64.9	194.7	52.7	142.0	185.7
3	Planlar1	F	51.4	154.2	30.4	123.8	138
4	Yeni Düzenltme	F	49.5	148.5	20.6	127.9	186.6
5	Apartmanla R Vize Tip B	F	28.1	84.2	24.9	59.3	59.2
6	Apt 99 Yeni	F	66.3	199.0	43.1	155.9	223.7
7	Apt 994-benid mimarlık	F	65	195.0	42.6	152.4	216
8	Ozgul	F	42.5	127.7	21.9	105.7	106.5
9	Dükkan PL2	F	52.4	157.3	19.1	138.2	122.5
10	Musa Apt.	F	33.6	101.0	24.5	76.5	60.3
11	Plan3	F	69.3	208.1	56.8	151.2	237

12	Plan4	F	69.8	209.5	44.8	164.7	182
13	Apartmnla A	F	29.8	89.5	24.7	64.7	64.7
14	A Blok Plan	F	26	78.0	14.1	63.9	63.8
15	Tony	F	52	156.0	24.7	131.3	131.5
				Avg.	**31.3**	**115.1**	**139.8**
					0.22	**0.82**	

- Avg.: Average

The Distribution of flats and semi-detached houses are different when the results of questionnaire and TRNC-Pry-Ministry Governmental Office of Planning, Population and House Causes, 2006 [37] are compared. However, we do not have enough information about the building components distribution in TRNC-Pry-Ministry Governmental Office of Planning, Population and House Causes, 2006. That is why the results of questionnaire will be used during the calculations.

On the other hand, when the characteristics properties of flats and semi-detached houses are compared it can be seen that area of window per unit area of houses are very closed to each others, net area of walls divides by 13.7%, and net area of houses divided by 7%.

In addition the average characteristics values of flat and semi-detached houses are very close to detached houses. Therefore, as an average it can be assumed that all the houses in North Cyprus have same characteristics properties, bringing us to the conclusion that the difference between questionnaire and TRNC-Pry-Ministry Governmental Office of Planning, Population and House Causes, 2006 will not effect the results considerably.

Table 6.18: Characteristics Properties of Detached, Semi-Detached and Flats.

Type	Average Net Area m^2	Average Wall Area m^2	Ratio of wall area to net area %	Average Window Area m^2	Ration of windows area to net area %
D	135.2	124.6	0.92	32.7	0.24
SD	129.9	123.5	0.95	28.1	0.21
F	139.8	115.1	0.82	31.3	0.22

Table 6.19: Calculations of Periphery.

	Room Wall Area (m^2)	Windows Area (m^2)	Living Room (m^2)	Window Living Room (m^2)	Kitchen Area (m^2)	Window Kitchen Area (m^2)	Total Area $(m)^2$	Periphery (m)
House 1								
Bed 1	11	7.4	29.3	30.1	13.5	5.18	129.3	50
Bed 2	14.5	3.84						
Bed 3	11	3.84						
Total	**36.5**	**14.7**	**29.3**	**30.1**	**13.5**	**5.18**	**129.3**	**50**

House 2								
Bed 1	19.3	7.2	24	8.3	19.11	2.6		
Bed 2	10.6	3.1						
Bed 3	10.5	6.9						
Total	**40.5**	**17.3**	**24**	**8.3**	**19.11**	**2.6**	**111.8**	**28.2**
House 3								
Bed 1	14.3	19.8	23.83	18	13.08	13.8		
Bed 2	14.1	19.8						
Bed 3	11.7	5.5						
Total	**40.2**	**45.2**	**23.83**	**18**	**13.08**	**13.8**	**154.2**	**77.1**
House 4								
Bed 1	12.3	7	27.81	23.1	12.3	3.8		
Bed 2	12.9	14						
Bed 3	12.9	14						
Total	**38.1**	**35.2**	**27.81**	**23.1**	**12.3**	**3.8**	**140.4**	**62.1**

Table 6.19: Calculations of Periphery (continued).

House 5								
Bed 1	14.5	6.76	32	25.7	12.5	10.8		
Bed 2	13	6.76						
Bed 3	16.5	8.4						
Total	**44**	**21.92**	**32**	**25.7**	**12.5**	**10.8**	**147**	**58.5**
House 6								
Bed 1	12.7	9.96	27.2	13.6	13.8	2.64		
Bed 2	16.5	8.4						
Bed 3	12.5	7.04						
Total	**41.7**	**25.4**	**27.2**	**13.6**	**13.8**	**2.64**	**124.4**	**41.7**
House 7								
Bed 1	9.3	4.68	33	18.5	15.7	7.92		
Bed 2	13.3	13.88						
Bed 3	10.7	11.84						
Total	**33.3**	**30.4**	**33**	**18.5**	**15.7**	**7.92**	**138.9**	**56.8**
House 8								
Bed 1	12.3	8.24	35.2	22.8	30	10.68		
Bed 2	16.6	14.24						
Bed 3	15.7	15.84						
Total	**44.6**	**38.32**	**35.2**	**22.8**	**30**	**10.68**	**181.6**	**71.8**
House 9								
Bed 1	10	5.4	20	7.9	11.8	6.48		
Bed 2	12.2	5.4						
Bed 3	15.9	5.72						
Total	**38.2**	**16.52**	**20**	**7.9**	**11.8**	**6.48**	**101**	**30.9**
House 10								
Bed 1	12.9	11.44	32.98	19.5	23.9	8.64		
Bed 2	18.7	4.68						
Bed 3	7.2	3.38						
Total	**38.8**	**19.5**	**32.98**	**19.5**	**23.9**	**8.64**	**143.4**	**47.6**
Average							**137.2**	**52.5**
Periphery *l*								**0.38 m/m^2**

6.6 Determination of Heat Loss of Houses per Unit Area per Degrees Centigrade

Having determined overall heat transfer coefficients for different types of building components, most frequently used, and the distribution of house types and building components in North Cyprus, heat loss calculation can now be conducted. For this purpose, Table 6.20, 6.21 and 6.22 were prepared for detached and semi-detached houses and flats. In these tables heat loss per meter square per degrees centigrade were calculated. The cases with non-zero percentages from Table 6.11, 6.12 and 6.13 were considered only.

Four different components of a house, namely, walls, windows floors and roofs were examined. In the first column, the types of building components are given. The second column shows the area of the building components per unit area of the house. Third column is used to write the overall heat transfer coefficients from Table 6.14. Since the calculations were conducted for 1ºC, the fourth column is all 1 except the temperature difference for the floor. The temperature difference between soil and inside of the house is assumed to be the half of the temperature difference between inside and outside of the house because the soil is always warmer than the air in winter times. The heat loss per meter square of a house can now be calculated using the equation

$$Q_0 = U\,A\Delta T$$

where Q_0 : Heat loss per unit area per degrees centigrade

U : Overall heat transfer coefficient

A : Area per unit area of the house

ΔT : Temperature difference

In column six infiltration coefficients, *a*, for windows are given. Windows with wooden, aluminum and PVC frames are assumed to have infiltration coefficients 3, 3 and 1, respectively. In column seven, periphery per unit area of a house, *l*, for windows are written, as it was calculated and given in Table 6.19. In column eight, nine and ten room coefficient, R, building coefficient, H, and coefficient for windows location, Ze, are assumed to be 0.9, 0.6 and 2.43 [12]. Now, heat for infiltration, Q_s, can be calculated using equation

$$Q_s = 1/3.6a\,l\,R\,H\,Ze\Delta\mathrm{T}\,.$$

Total heat loss per unit area per meter square per degrees centigrade can then be calculated by adding Q_0 and Q_s and given in column twelve. The effect of building height and direction were not considered. The heat loss calculations were conducted during the steady state conditions.

Table 6.20: Determination of Heat Loss of Houses per m^2 per ^oC in Detached Houses.

Building Comp.		Heat Loss Calculations			Infiltration						
	Area per Unit Area	Heat Tr. Coeff.	Temp. Diff.	Heat Loss per unit area	Infiltration coefficient	Periphery	Room Coefficient	Building Coefficient		Heat for Infiltration	Total Heat Loss per unit area
		U	T	Qo	a	I	R	H	Ze	Qs	Q
	m^2/m^2	$W/m^2\,^oC$	^oC	W/m^2	m3/m	m/m^2		KJ/m3 ^oC		W/m^2C	W/m^2C
Case No. 1											
P-TB-P	0.92	1.5	1	1.38							
SG-wood	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.87						0.83	**6.71**
Case No. 2											
P-TB-P	0.92	1.5	1	1.38							
DG-wood	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.25						0.83	**6.08**
Case No. 3											
P-TB-P	0.92	1.5	1	1.38							
SG-AL	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.87						0.83	**6.71**
Case No. 4											
P-TB-P	0.92	1.5	1	1.38							
DG-AL	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.25						0.83	**6.08**

Case No. 5											
P-TB-P	0.92	1.5	1	1.38							
SG-PVC	0.24	5.6	1	1.34	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TAL	3.16			5.87							**5.87**
Case No. 6											
P-TB-P	0.92	1.5	1	1.38							
DG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							

Table 6.20: Determination of Heat Loss of Houses per m^2 per ^{o}C in Detached Houses (continued).

C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.25						0.28	**5.53**
Case No. 7											
P-CB-P	0.92	0.7	1	0.64							
SG-wood	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.14						0.83	**5.97**
Case No. 8											
P-TB-P	0.92	1.5	1	1.38							
DG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.25							**5.25**
Case No. 9											
P-CB-P	0.92	0.7	1	0.64							
SG-AL	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.14						0.83	**5.97**
Case No. 10											
P-CB-P	0.92	0.7	1	0.64							
DG-AL	0.24	5.6	1	1.34	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.14						0.28	**5.42**
Case No. 11											
P-CB-P		0.92	1.5	1	1.38						
DG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.25							**5.25**
Case No. 12											
P-CB-P		0.92	1.5	1	1.38						

DG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.25							**5.25**

Case No. 13

P-TB-P		0.92	1.5	1	1.38						
SG-wood	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.47							**4.47**

Table 6.20: Determination of Heat Loss of Houses per m^2 per ^{o}C in Detached Houses (continued).

Case No. 14

P-TB-P		0.92	1.5	1	1.38						
DG-wood	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			5.25							**5.25**

Case No. 15

P-TB-P	0.92	1.5	1	1.38							
SG-AL	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.47						0.83	**5.31**

Case No. 16

P-TB-P	0.92	1.5	1	1.38							
DG-AL	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.47						0.83	**5.31**

Case No. 17

P-TB-P	0.92	1.5	1	1.38							
SG-PVC	0.24	5.6	1	1.34	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.47						0.28	**4.75**

Case No. 18

P-TB-P	0.92	1.5	1	1.38							
DG-PVC	0.24	5.6	1	1.34	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.47						0.28	**4.75**

Case No. 19

P-CB-P	0.92	0.7	1	0.64							
SG-wood	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			3.11						0.83	**3.95**

Case No. 20

P-CB-P	0.92	0.7	1	0.64							
DG-wood	0.24	5.6	1	1.34	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			3.74						0.28	**4.02**

Case No. 21

P-CB-P	0.92	0.7	1	0.64

Table 6.20: Determination of Heat Loss of Houses per m^2 per ^oC in Detached Houses (continued).

SG-AL	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			3.11						0.83	**3.95**

Case No. 22

P-CB-P	0.92	0.7	1	0.64							
DG-AL	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			3.74						0.83	**4.57**

Case No. 23

P-CB-P	0.92	0.7	1	0.64							
SG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			3.11						0.28	**3.39**

Case No. 24

P-CB-P	0.92	0.7	1	0.64							
DG-PVC	0.24	5.6	1	1.34	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			3.74						0.28	**4.02**

Case No. 25

P-TB-I-P	0.92	0.5	1	0.46							
SG-wood	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.33						0.83	**5.16**

Case No. 26

P-TB-I-P	0.92	0.5	1	0.46							
DG-wood	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			3.55						0.83	**4.39**

Case No. 27

P-TB-I-P	0.92	0.5	1	0.46							
SG-AL	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.95						0.83	**5.79**

Case No. 28

P-TB-I-P	0.92	0.5	1	0.46							
DG-AL	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.33						0.83	**5.16**

Table 6.20: Determination of Heat Loss of Houses per m^2 per ^{o}C in Detached Houses (continued).

Case No. 29

P-TB-I-P	0.92	0.5	1	0.46							
SG-PVC	0.24	5.6	1	1.34	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.95						0.28	**5.23**

Case No. 30

P-TB-I-P	0.92	0.5	1	0.46							
DG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.33						0.28	**4.61**

Case No. 31

P-CB-I-P	0.92	0.4	1	0.37							
SG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.24						0.28	**4.52**

Case No. 32

P-CB-I-P	0.92	0.4	1	0.37							
DG-wood	0.24	5.6	1	1.34	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.86						0.83	**5.69**

Case No. 33

P-CB-I-P	0.92	0.4	1	0.37							
SG-AL	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.24						0.83	**5.07**

Case No. 34

P-CB-I-P	0.92	0.4	1	0.37							
DG-AL	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.24						0.83	**5.07**

Case No. 35											
P-CB-I-P	0.92	0.4	1	0.37							
SG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.24						0.28	**4.52**
Case No. 36											
P-CB-I-P	0.92	0.4	1	0.37							
DG-PVC	0.24	5.6	1	1.34	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1	2	1	2.00							

Table 6.20: Determination of Heat Loss of Houses per m^2 per ^{o}C in Detached Houses (continued).

C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			4.86						0.28	**5.14**
Case No. 37											
P-TB-I-P	0.92	0.5	1	0.46							
SG-wood	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.93						0.83	**3.76**
Case No. 38											
P-TB-I-P	0.92	0.5	1	0.46							
DG-wood	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.93						0.83	**3.76**
Case No. 39											
P-TB-I-P	0.92	0.5	1	0.46							
SG-AL	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.93						0.83	**3.76**
Case No. 40											
P-I-TB-P	0.92	0.5	1	0.46							
DG-AL	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.93						0.83	**3.76**
Case No. 41											
P-TB-I-P	0.92	0.5	1	0.46							
SG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.93						0.28	**3.21**
Case No. 42											
P-I-TB-P	0.92	0.5	1	0.46							

DG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.93						0.28	**3.21**

Case No. 43

P-CB-I-P	0.92	0.4	1	0.37							
SG-wood	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.84						0.83	**3.67**

Table 6.20: Determination of Heat Loss of Houses per m^2 per ^{o}C in Detached Houses (continued).

Case No. 44

P-CB-I-P	0.92	0.4	1	0.37							
DG-wood	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.84						0.83	**3.67**

Case No. 45

P-CB-I-P	0.92	0.4	1	0.37							
DG-wood	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.84						0.83	**3.67**

Case No. 46

P-I-CB-P	0.92	0.4	1	0.37							
DG-AL	0.24	3	1	0.72	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.84						0.83	**3.67**

Case No. 47

P-I-CB-P	0.92	0.4	1	0.37							
SG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.84						0.28	**3.12**

Case No. 48

P-I-CB-P	0.92	0.4	1	0.37							
DG-PVC	0.24	3	1	0.72	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1	0.6	1	0.60							
C-F-NI	1	2.3	0.5	1.15							
TOTAL	3.16			2.84						0.28	**3.12**

Table 6.21: Determination of Heat Loss of Houses per m^2 per ^oC in Semi-Detached Houses.

Building Comp.		Heat Loss Calculations			Infiltration						
	Area per Unit Area	Heat Tr. Coeff.	Temp. Diff.	Heat Loss per unit area	Infiltration coefficient	Periphery	Room Coefficient	Building Coefficient		Heat for Infiltration	Total Heat Loss per unit area
		U	T	Qo	a	I	R	H	Ze	Qs	Q
	m^2/m^2	W/m^2 ^oC	^oC	W/m^2		m/m^2				W/m^2	W/m^2
Case No. 1											
P-TB-P	0.95	1.5	1	1.43							
SG -wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			5.81						0.83	**6.64**
Case No. 2											
P-TB-P	0.95	1.5	1	1.43							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			5.24						0.83	**6.07**
Case No. 3											
P-TB-P	0.95	1.5	1	1.43							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			5.81						0.83	**6.64**
Case No. 4											
P-TB-P	0.95	1.5	1	1.43							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			5.24						0.83	**6.07**
Case No. 5											
P-TB-P	0.95	1.5	1	1.43							

SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			5.81						0.28	**6.08**
Case No. 6											
P-TB-P	0.95	1.5	1	1.43							
DG-PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			5.24						0.28	**5.51**
Case No. 7											
P-CB-P	0.95	0.7	1	0.67							
SG -wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	

Table 6.21: Determination of Heat Loss of Houses per m^2 per ^oC in Semi-Detached Houses.

C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			5.05						0.83	**5.88**
Case No. 8											
P-CB-P	0.95	0.7	1	0.67							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.48						0.83	**5.31**
Case No. 9											
P-CB-P	0.95	0.7	1	0.67							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			5.05						0.83	**5.88**
Case No. 10											
P-CB-P	0.95	0.7	1	0.67							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.48						0.83	**5.31**
Case No. 11											
P-CB-P	0.95	0.7	1	0.67							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			5.05						0.28	**5.32**
Case No. 12											
P-CB-P	0.95	0.7	1	0.67							
DG-PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.48						0.28	**4.75**
Case No. 13											
P-TB-P	0.95	1.5	1	1.43							
SG -wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							

TOTAL	3.17			4.41						0.83	**5.24**
Case No. 14											
P-TB-P	0.95	1.5	1	1.43							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.84						0.83	**4.67**
Case No. 15											
P-TB-P	0.95	1.5	1	1.43							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			5.81						0.83	**6.64**

Table 6.21: Determination of Heat Loss of Houses per m^2 per ^{o}C in Semi-Detached Houses (continued).

Case No. 16											
P-TB-P	0.95	1.5	1	1.43							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.84						0.83	**4.67**
Case No. 17											
P-TB-P	0.95	1.5	1	1.43							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.41						0.28	**4.68**
Case No. 18											
P-TB-P	0.95	1.5	1	1.43							
DG-PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.84						0.28	**4.11**
Case No. 19											
P-CB-P	0.95	0.7	1	0.67							
SG -wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.65						0.83	**4.48**
Case No. 20											
P-CB-P	0.95	0.7	1	0.67							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.08						0.83	**3.91**
Case No. 21											
P-CB-P	0.95	0.7	1	0.67							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.65						0.83	**4.48**
Case No. 22											
P-CB-P	0.95	0.7	1	0.67							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							

C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.08						0.83	**3.91**
Case No. 23											
P-CB-P	0.95	0.7	1	0.67							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.65						0.28	**3.92**
Case No. 24											
P-CB-P	0.95	0.7	1	0.67							
DG-PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	

Table 6.21: Determination of Heat Loss of Houses per m^2 per ^oC in Semi-Detached Houses (continued).

C-R-I	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.48						0.28	**4.75**
Case No. 25											
P-TB-I-P	0.95	0.52	1	0.49							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.88						0.83	**5.71**
Case No. 26											
P-TB-I-P	0.95	0.52	1	0.49							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.30						0.83	**5.14**
Case No. 27											
P-TB-I-P	0.95	0.52	1	0.49							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.88						0.83	**5.71**
Case No. 28											
P-TB-I-P	0.95	0.52	1	0.49							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.30						0.83	**5.14**
Case No. 29											
P-TB-I-P	0.95	0.52	1	0.49							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.88						0.28	**5.15**
Case No. 30											
P-TB-I-P	0.95	0.52	1	0.49							
DG-PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.30						0.28	**4.58**
Case No. 31											

P-CB-I-P	0.95	0.4	1	0.38							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.76						0.83	**5.59**
Case No. 32											
P-CB-I-P	0.95	0.4	1	0.38							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.19						0.83	**5.02**

Table 6.21: Determination of Heat Loss of Houses per m^2 per ^{o}C in Semi-Detached Houses (continued).

Case No. 33											
P-CB-I-P	0.95	0.4	1	0.38							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.76						0.83	**5.59**
Case No. 34											
P-CB-I-P	0.95	0.4	1	0.38							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.19						0.83	**5.02**
Case No. 35											
P-CB-I-P	0.95	0.4	1	0.38							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.76						0.28	**5.04**
Case No. 36											
P-CB-I-P	0.95	0.4	1	0.38							
DG-PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			4.19						0.28	**4.47**
Case No. 37											
P-TB-I-P	0.95	0.52	1	0.49							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.48						0.83	**4.31**
Case No. 38											
P-TB-I-P	0.95	0.52	1	0.49							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			2.90						0.83	**3.74**
Case No. 39											
P-TB-I-P	0.95	0.52	1	0.49							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							

TOTAL	3.17			3.48						0.83	**4.31**
Case No. 40											
P-TB-I-P	0.95	0.52	1	0.49							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			2.90						0.83	**3.74**
Case No. 41											
P-TB-I-P	0.95	0.52	1	0.49							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							

Table 6.21: Determination of Heat Loss of Houses per m^2 per ^{o}C in Semi-Detached Houses (continued).

TOTAL	3.17			3.48						0.28	**3.75**
Case No. 42											
P-TB-I-P	0.95	0.52	1	0.49							
DG-PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			2.90						0.28	**3.18**
Case No. 43											
P-CB-I-P	0.95	0.4	1	0.38							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.36						0.83	**4.19**
Case No. 44											
P-CB-I-P	0.95	0.4	1	0.38							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			2.79						0.83	**3.62**
Case No. 45											
P-CB-I-P	0.95	0.4	1	0.38							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.36						0.83	**4.19**
Case No. 46											
P-CB-I-P	0.95	0.4	1	0.38							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			2.79						0.83	**3.62**
Case No. 47											
P-CB-I-P	0.95	0.4	1	0.38							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			3.36						0.28	**3.64**
Case No. 48											
P-I-CB-P	0.95	0.4	1	0.38							
DG -PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	

C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.17			2.79						0.28	**3.07**

Table 6.22: Determination of Heat Loss of Houses per m^2 per ^{o}C in Flat Houses.

Building Comp.		Heat Loss Calculations			Infiltration						
	Area per Unit Area	Heat Tr. Coeff.	Temp. Diff.	Heat Loss per unit area	Infiltration coefficient	Periphery	Room Coefficient	Building Coefficient		Heat for Infiltration	Total Heat Loss per unit area
		U	T	Qo	a	I	R	H	Ze	Qs	Q
	m^2/m^2	W/ m^2 ^{o}C	^{o}C	W/m^2		m/m^2				W/ m^2	W/ m^2
Case No. 1											
P-TB-P	0.82	1.5	1	1.23							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			5.61						0.83	6.44
Case No. 2											
P-TB-P	0.82	1.5	1	1.23							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			5.04						0.83	5.87
Case No. 3											
P-TB-P	0.82	1.5	1	1.23							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			5.61						0.83	6.44
Case No. 4											
P-TB-P	0.82	1.5	1	1.23							
DG-AL	0.22	3.0	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			5.04						0.83	5.87
Case No. 5											
P-TB-P	0.82	1.5	1	1.23							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							

TOTAL	3.04			5.61						0.28	5.89
Case No. 6											
P-TB-P	0.82	1.5	1	1.23							
DG-PVC	0.22	3	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			5.04						0.28	5.32
Case No. 7											
P-CB-P	0.82	0.7	1	0.57							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							

Table 6.22: Determination of Heat Loss of Houses per m^2 per ^{o}C in Flat Houses (continued).

TOTAL	3.04			4.96						0.83	5.79
Case No. 8											
P-CB-P	0.82	0.7	1	0.57							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.38						0.83	5.22
Case No. 9											
P-CB-P	0.82	0.7	1	0.57							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.96						0.83	5.79
Case No. 10											
P-CB-P	0.82	0.7	1	0.57							
DG-AL	0.22	3.0	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.38						0.83	5.22
Case No. 11											
P-TB-P	0.82	1.5	1	1.23							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			5.61						0.28	5.89
Case No. 12											
P-CB-P	0.82	0.7	1	0.57							
DG-PVC	0.22	3	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.38						0.28	4.66
Case No.13											
P-TB-P	0.82	1.5	1	1.23							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.21						0.83	5.04
Case No. 14											
P-TB-P	0.82	1.5	1	1.23							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	

C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.64						0.83	4.47
Case No. 15											
P-TB-P	0.82	1.5	1	1.23							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.21						0.83	5.04
Case No. 16											
P-TB-P	0.82	1.5	1	1.23							
DG-AL	0.22	3.0	1	0.66	3	0.38	0.9	2.43	1.2	0.83	

Table 6.22: Determination of Heat Loss of Houses per m^2 per ^oC in Flat Houses (continued).

C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.64						0.83	4.47
Case No. 17											
P-TB-P	0.82	1.5	1	1.23							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.21						0.28	4.49
Case No. 18											
P-TB-P	0.82	1.5	1	1.23							
DG-PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.64						0.28	3.92
Case No. 19											
P-CB-P	0.82	0.7	1	0.57							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.56						0.83	4.39
Case No. 20											
P-CB-P	0.82	0.7	1	0.57							
DG-wood	0.22	3.0	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			2.98						0.83	3.82
Case No. 21											
P-CB-P	0.82	0.7	1	0.57							
SG -AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.56						0.83	4.39
Case No. 22											
P-CB-P	0.82	0.7	1	0.57							
DG-PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			2.98						0.28	3.26
Case No. 23											

P-CB-P	0.82	0.7	1	0.57							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.56						0.83	4.39
Case No. 24											
P-CB-P	0.82	0.7	1	0.57							
DG-PVC	0.22	3	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			2.98						0.28	3.26

Table 6.22: Determination of Heat Loss of Houses per m^2 per ^oC in Flat Houses (continued).

Case No.25											
P-TB-I-P	0.82	0.52	1	0.43							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.81						0.83	5.64
Case No. 26											
P-TB-I-P	0.82	0.52	1	0.43							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.24						0.83	5.07
Case No. 27											
P-TB-I-P	0.82	0.52	1	0.43							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.81						0.83	5.64
Case No. 28											
P-TB-I-P	0.82	0.52	1	0.43							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.24						0.83	5.07
Case No. 29											
P-TB-I-P	0.82	0.52	1	0.43							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.81						0.28	5.09
Case No. 30											
P-TB-I-P	0.82	0.7	1	0.57							
DG-PVC	0.22	3	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.38						0.28	4.66
Case No. 31											
P-CB-I-P	0.82	0.4	1	0.33							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2.0	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							

TOTAL	3.04			4.71						0.83	5.54
Case No. 32											
P-CB-I-P	0.82	0.4	1	0.33							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.14						0.83	4.97
Case No. 33											
P-CB-I-P	0.82	0.4	1	0.33							
SG - AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							

Table 6.22: Determination of Heat Loss of Houses per m^2 per ^{o}C in Flat Houses (continued).

TOTAL	3.04			4.71						0.83	5.54
Case No. 34											
P-CB-I-P	0.82	0.4	1	0.33							
DG-AL	0.22	3.0	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-NI	1.00	2	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.14						0.83	4.97
Case No. 35											
P-CB-I-P	0.82	0.4	1	0.33							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			4.71						0.28	4.99
Case No. 36											
P-CB-I-P	0.82	0.04	1	0.03							
DG -PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-NI	1.00	2	1	2.00							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.84						0.28	4.12
Case No. 37											
P-TB-I-P	0.82	0.52	1	0.43							
SG –wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.41						0.83	4.24
Case No. 38											
P-TB-I-P	0.82	0.52	1	0.43							
DG –wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			2.84						0.83	3.67
Case No. 39											
P-TB-I-P	0.82	0.52	1	0.43							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.41						0.83	4.24
Case No. 40											
P-TB-I-P	0.82	0.52	1	0.43							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	

Table 6.22: Determination of Heat Loss of Houses per m^2 per ^{o}C in Flat Houses (continued).

C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			2.84						0.83	3.67
Case No. 41											
P-TB-I-P	0.82	0.52	1	0.43							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.41						0.28	3.69
Case No. 42											
P-TB-I-P	0.82	0.52	1	0.43							
DG-PVC	0.22	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			2.84						0.28	3.11
Case No. 43											
P-CB-I-P	0.82	0.4	1	0.33							
SG-wood	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.31						0.83	4.14
Case No. 44											
P-CB-I-P	0.82	0.4	1	0.33							
DG-wood	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			2.74						0.83	3.57
Case No. 45											
P-CB-I-P	0.82	0.4	1	0.33							
SG-AL	0.22	5.6	1	1.23	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.31						0.83	4.14
Case No. 46											
P-CB-I-P	0.82	0.4	1	0.33							
DG-AL	0.22	3	1	0.66	3	0.38	0.9	2.43	1.2	0.83	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			2.74						0.83	3.57
Case No. 47											
P-CB-I-P	0.82	0.4	1	0.33							
SG-PVC	0.22	5.6	1	1.23	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			3.31						0.28	3.59
Case No. 48											
P-CB-I-P	0.82	0.4	1	0.33							
DG-PVC	0.22	3	1	0.66	1	0.38	0.9	2.43	1.2	0.28	
C-R-I	1.00	0.6	1	0.60							
C-F-NI	1.00	2.3	0.5	1.15							
TOTAL	3.04			2.74						0.28	3.02

6.7 Determination of Total Energy Loss per Year

Having determined the total heat loss per unit area per degree centigrade for all the cases the average heat loss per meter square per degrees centigrade for three different types of houses components in North Cyprus, can now be calculated according to the distribution of building components. Table 6.23, 6.24, and 6.25 were prepared for detached and semi-detached houses, and flats, respectively. In these tables the average heat loss per meter square per degrees centigrade were calculated for cases given in Tables 6.20, 6.21 and 6.22.

In Tables 6.23, 6.24 and 6.25, in the first column the cases numbers can be seen which they were obtained from Tables 6.20, 6.21 and 6.22, in the second column the type of houses shown, the third column shows the building components used. The fourth and fifth columns give information about wall and roof insulation, respectively (insulated or non-insulated). Column six shows the window materials, namely, wood, aluminum or PVC. Column seven shows the window glazing (single glazing or double glazing). Column eight and nine show the number and percentage of houses having specified building components according to the questionnaire. Column ten shows the heat loss data from Tables 6.20, 6.21, and 6.22. In the last column the contributions of the distribution of building components to average heat loss per meter square per degrees centigrade are given. In the last row of the last column the of Tables 6.23, 6.24, and 6.25 the contribution of three types of house to an average North Cyprus house were calculated by adding the contribution of building components.

In Table 6.26 the total energy loss per ^{o}C of an average house in North Cyprus was determined as 941.1 W/^{o}C by multiplying the contributions of detached and semi-detached houses and flats by their average net area and adding the results.

Table 6.23: Determinations of Average Heat Loss per m^2 per ^{o}C in Detached Houses.

Case No.	Detached	Material	Wall	Roof	Window	Glazing	# 0f houses	% of houses	Q	Q/%
1	D	TB	NI	NI	Wood	SG	23	10.088%	6.71	0.67
3	D	TB	NI	NI	AL	SG	63	27.632%	6.71	1.85
4	D	TB	NI	NI	AL	DG	12	5.263%	6.08	0.32

6	D	TB	NI	NI	PVC	DG	2	0.877%	5.53	0.048
7	D	CB	NI	NI	Wood	SG	3	1.316%	5.97	0.078
9	D	CB	NI	NI	AL	SG	7	3.070%	5.97	0.18
10	D	CB	NI	NI	AL	DG	1	0.439%	4.79	0.02
15	D	TB	NI	I	AL	SG	2	0.877%	5.31	0.046
25	D	TB	I	NI	Wood	SG	1	0.439%	5.79	0.025
27	D	TB	I	NI	AL	SG	1	0.439%	5.79	0.025
38	D	TB	I	I	Wood	DG	2	0.877%	3.76	0.032
40	D	TB	I	I	AL	DG	1	0.439%	3.76	0.016
42	D	TB	I	I	PVC	DG	1	0.439%	3.21	0.014
46	D	CB	I	I	AL	DG	1	0.439%	3.67	0.016
Total							120	52%		3.347

Table 6.24: Determinations of Average Heat Loss per m^2 per ^{o}C in Semi-Detached Houses.

Case No,	Semi-Detached	Material	Wall	Roof	Window	Glazing	# of houses	% of houses	Q	Q/%
1	SD	TB	NI	NI	Wood	SG	4	1.754%	6.71	0.117
3	SD	TB	NI	NI	AL	SG	5	2.193%	6.71	0.147
6	SD	TB	NI	NI	PVC	DG	2	0.877%	5.53	0.048
48	SD	CB	I	I	PVC	DG	1	0.439%	3.12	0.0136
Total							12	5%		0.3256

Table 6.25: Determinations of Average Heat Loss per m^2 per ^{o}C in Flat Houses.

Case No.	Flats	Material	Wall	Roof	Window	Glazing	# of houses	% of houses	Q	Q/%
1	F	TB	NI	NI	Wood	SG	3	1.316%	6.71	0.088
3	F	TB	NI	NI	AL	SG	67	29.386%	6.71	1.97
4	F	TB	NI	NI	AL	DG	6	2.632%	6.08	0.16
7	F	CB	NI	NI	Wood	SG	2	0.877%	5.97	0.052
9	F	CB	NI	NI	AL	SG	4	1.754%	5.97	0.1
10	F	CB	NI	NI	AL	DG	1	0.439%	5.35	0.024
15	F	TB	NI	I	AL	SG	3	1.316%	5.31	0.069
16	F	TB	NI	I	AL	DG	2	0.877%	4.47	0.039
18	F	TB	NI	I	PVC	DG	1	0.439%	4.13	0.018
21	F	CB	NI	I	AL	SG	1	0.439%	4.57	0.02
23	F	CB	NI	I	PVC	SG	1	0.439%	4.02	0.017
39	F	TB	I	I	AL	SG	2	0.877%	4.75	0.0416
41	F	TB	I	I	PVC	SG	1	0.439%	4.2	0.018
42	F	TB	I	I	PVC	DG	1	0.439%	3.58	0.0157
47	F	CB	I	I	PVC	SG	1	0.439%	3.74	0.016
Total							96	42%		2.648

Table 6.26: Total Energy Loss per ^{o}C of an Average House in North Cyprus.

Type	Total Q	Average Area	Average heat loss of houses per ^{o}C in North Cyprus (W/^{o}C)
D	3.347	135	451.84
SD	0.3256	130	42.32

F	2.648	140	370.71
		Total	864.9

In a regular family adults work during day time and children are at school. Although most of the primary and high schools in North Cyprus are until noon, children have some other activities outside. So there will be nobody at home during day times. Besides, even for the coldest month there is not much heating requirement during day times. Generally, the time between 00:00 to 06:00 is sleeping hours for adults where this period is longer for children and may be shorter for older people. Therefore, it can be assumed that daily heating period in a house is from 06:00 to 08:00 and from 18:00 to 24:00, adding up to eight hours per day.

Monthly average yearly minimum temperature distribution of Nicosia can be seen in Table 6.27. As it can be seen from the table from May to October the minimum temperatures are above 15 C and no heating is required. Being bellow 15 C November to April can be considered as the yearly heating period.

Table 6.27: The Average Monthly Climate Indicators in Nicosia Based on 8 Years of Historical Weather Readings [44].

NICOSIA 35 15 N, 33 40 E, 161 meters (528 feet) above sea level.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (C^0)	12	12	15	20	26	30	32	32	28	24	17	13
Avg. Max Temperature (C^0)	14	15	18	23	29	33	36	36	32	27	20	16
Avg. Min Temperature (C^0)	5.4	5.5	7	10.4	15	19	21	21	18	15	9.9	6.8
Avg. Rain Days	5	3	3	1	1	0	0	0	0	1	3	3
Avg. Snow Days	0	0	0	0	0	0	0	0	0	0	0	0

Considering comfortable temperature of a house as 22 ^oC the monthly average maximum temperature differences can be calculated for the months of heating period and the heat loss of an average house can be calculated by multiply those temperature differences by the total energy loss per ^oC of an average house in North Cyprus as shown in Table 6.28. These values can be converted to daily and monthly totals. Adding up the monthly totals the total heat loss per house can be calculated for an average house in North Cyprus during the heating period, it should be considered that this value is for houses having central heating systems. Assuming that the half of a house is heated if local heating is used and including the effect of local and central heating house percentages total heat loss per house during heating period can be calculated as 36076 MJ.

To find out the total energy loss per house per year it is assumed that for cooling the same amount of energy is lost during the remaining six months. However, cooling is almost local. Therefore, half of total heat loss is multiplied by 2 to give the total energy loss per year per house approximately. By multiplying this number by the number of active houses in North Cyprus the total energy loss was estimated to be 4881 million MJ per year.

Table 6.28: Estimation of Heat Loss per Year in North Cyprus.

	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	864.9						
Nov.		22	9.9	12.1	10465.29	301.4	9042.01
Dec.			6.8	15.2	13146.48	378.61	11358.55
Jan.			5.4	16.6	14357.34	413.49	12404.74
Feb.			5.5	16.5	14270.85	447.19	13415.85
Mar.			7.0	15.0	12973.5	411	12330.01
Apr.			10.4	11.6	10032.84	288.94	8668.37
TOTAL Heat Loss per house (Central Heating) (MJ)							67219.53
TOTAL Energy Loss in North Cyprus (million MJ)							4881.75

Total energy loss per year per country in the year 2001 is given in Figures 6.26 and 6.27 in million MJ and percentages, respectively, together with the data estimated for North Cyprus. As it can be seen North Cyprus has a lower energy loss when compared with EU countries, because it is an island with a relative low population.

To see the level of energy loss in a country, the energy loss through the unit area of walls and roofs is a measure and will be considered in the following two sections.

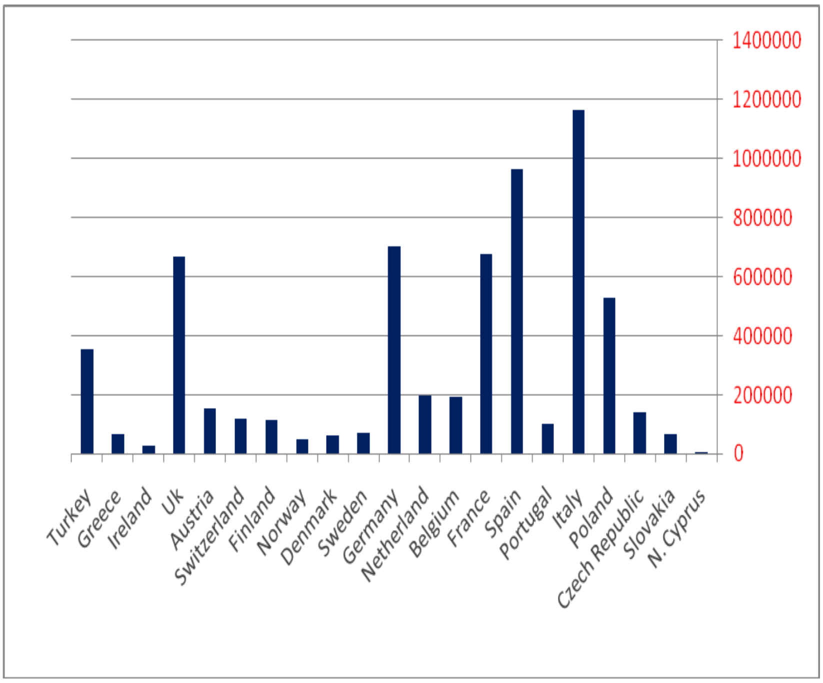


Figure 6.26: Total Energy Loss per Year, 2001 (million MJ/ year / house).

N. Cyprus	1637
Slovakia	1350000
Czech Rep	2575000
Poland	9650000
Italy	14375000
Portugal	2500000
Spain	9975000
France	14875000
Belgium	2575000
Netherland	3975000
Germany	20500000
Sweden	2200000
Denmark	1325000
Norway	1125000
Finland	1300000
Switzerland	1800000
Austria	2025000
UK	14875000
Ireland	950000
Greece	2650000
Turkey	16900000

N. Cyprus	0.1%
Slovakia	1.0%
Czech Rep.	2.2%
Poland	8.2%
Italy	18.2%
Portugal	1.6%
Spain	15.0%
France	10.5%
Belgium	3.0%
Netherland	3.1%
Germany	11.0%
Sweden	1.1%
Denmark	1.0%
Norway	0.7%
Finland	1.8%

Switzerland	1.9%
Austria	2.4%
Uk	10.4%
Ireland	0.4%
Greece	1.0%
Turkey	5.5%

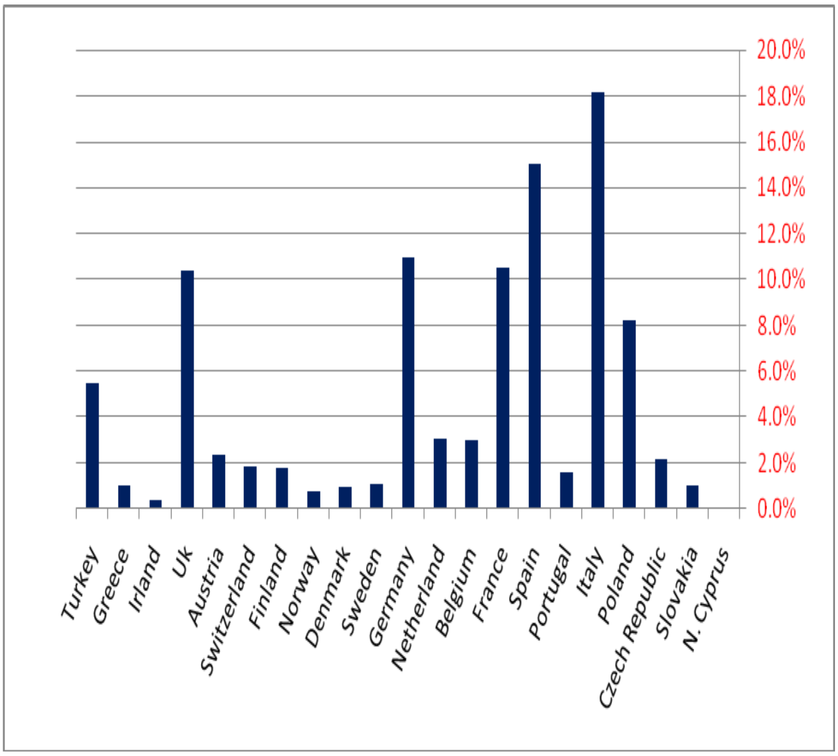


Figure 6.27: Total Energy Loss per Country, 2001 (%).

6.8 Estimation of Energy Loss Through Walls of Houses in North Cyprus

Table 6.29: Determination of Heat Loss per Unit Area per Degrees Centigrade of Typical Wall Types.

Building Comp.		Heat Loss Calculations		
	Area per Unit Area	Heat Tr. Coeff.	Temp. Diff.	Heat Loss per unit area
		k	T	Qo
	m^2/m^2	$W/m^2\ {}^oC$	^oC	$W/\ m^2\ {}^oC$
P-TB-P	1.00	1.50	1	1.50
P-CB-P	1.00	0.69	1	0.69
P-TB-I-P	1.00	0.50	1	0.50
P-CB-I-P	1.00	0.40	1	0.40

Table 6.29 shows heat loss calculations per unit area per degrees centigrade of typical wall types used in North Cyprus, which can be given as follows:

- P-TB-P: Plaster-Terracotta Brick-Plaster

- P-CB-P: Plaster-Concrete Blocks-Plaster
- P-TB-I-P: Plaster-Terracotta Brick-Insulation-Plaster
- P-CB-I-P: Plaster-Concrete Blocks-Insulation-Plaster

Overall heat transfer coefficients are taken from Table 6.14, Energy loss per meter square per year for different wall types were calculated and presented in Tables 6.29, 6.30, 6.31, and 6.32 with a similar methodology to Table 6.28. By including the distribution of wall types in North Cyprus, energy loss per meter square per year of an average wall can be determined and presented in Table 6.33.

Table 6.30: Determination of Energy Loss per Year in Terrecotta Tricks without Insulation in North Cyprus.

	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
P-TB-P	1.5						
Nov.		22	9.9	12.1	18.15	0.24	7.21
Dec.			6.8	15.2	22.8	0.30	9.06
Jan.			5.4	16.6	24.9	0.33	9.90
Feb.			5.5	16.5	24.75	0.33	9.84
Mar.			7.0	15.0	22.5	0.30	8.94
Apr.			10.4	11.6	1.2	0.23	6.92
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							51.87
TOTAL Heat Loss per m^2 (Heating)							26.45

Table 6.31: Determination of Energy Loss per Year in Concrete without Insulation in North Cyprus.

	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
P-CB-P	0.69						
Nov.		22	9.9	12.1	8.35	0.24	7.21
Dec.			6.8	15.2	10.49	0.30	9.06
Jan.			5.4	16.6	11.45	0.33	9.90
Feb.			5.5	16.5	11.39	0.33	9.84
Mar.			7.0	15.0	10.35	0.30	8.94
Apr.			10.4	11.6	8.00	0.23	6.92
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							51.87
TOTAL Heat Loss per m^2 (Heating)							26.45

Table 6.32: Determination of Energy Loss per Year in Terracotta Bricks with Insulation in North Cyprus.

	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
P-TB-I-P	0.50						
Nov.		22	9.9	12.1	6.05	0.17	5.23
Dec.			6.8	15.2	7.60	0.22	6.57
Jan.			5.4	16.6	8.30	0.24	7.17
Feb.			5.5	16.5	8.25	0.24	7.13
Mar.			7.0	15.0	7.50	0.22	6.48
Apr.			10.4	11.6	5.80	0.17	5.01
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							37.58
TOTAL Heat Loss per m^2 (Heating)							19.17

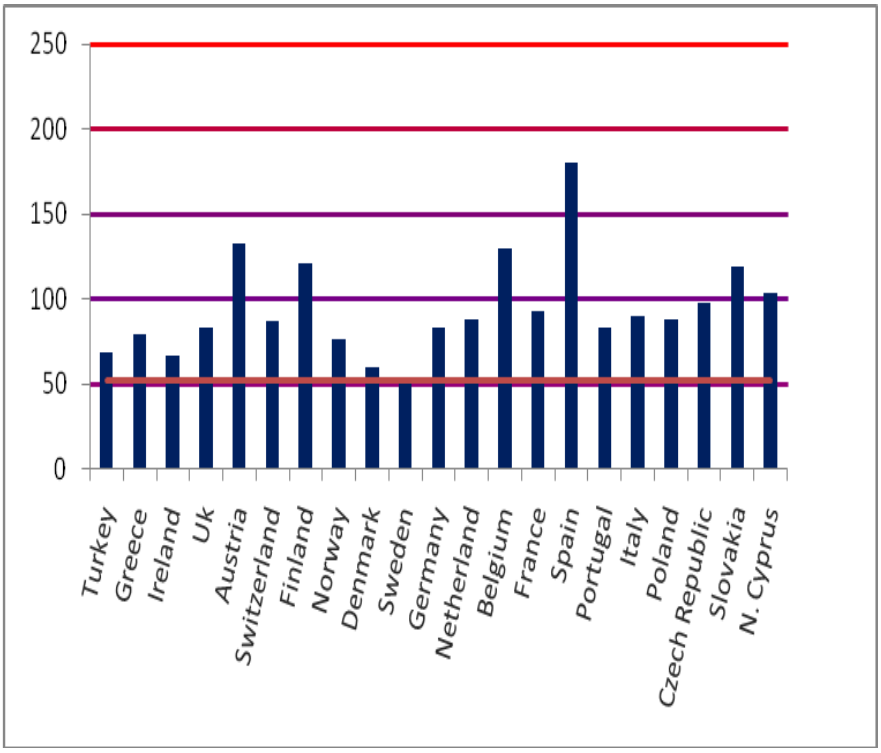
Table 6.33: Determination of Energy Loss per Year in Concrete with Insulation in North Cyprus.

	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
P-CB-I-P	0.40						
Nov.		22	9.9	12.1	4.84	0.14	4.18
Dec.			6.8	15.2	6.08	0.18	5.25
Jan.			5.4	16.6	6.64	0.19	5.74
Feb.			5.5	16.5	6.60	0.19	5.70
Mar.			7.0	15.0	6.00	0.17	5.18
Apr.			10.4	11.6	4.64	0.13	4.01
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							30.07
TOTAL Heat Loss per m^2 (Heating)							15.33

Table 6.34: Total Determination of Energy Loss per Year in Wall Materials with/without Insulation in North Cyprus.

Type of Wall Material	No. of Houses	Percentages %	Total Energy Loss per m2	Total Energy Loss by %
P-TB-P	199	86.1%	112.7	97.13
P-TBI-P	11	4.7%	37.5	1.78
P-CB-P	18	7.8%	51.8	4.04
P-CBI-P	3	1.30%	30.1	0.39
TOTAL	231	100.00%	213.5	103.35

Figure 6.28 represents the situation of North Cyprus among EU countries. Unlike total energy loss per year per country, energy loss through wall of North Cyprus per meter square is higher (103 MJ/m^2 per year), when compared with the other countries because of poor insulation. The walls must be constructed or modified as required to drop this value to the required level of 52 MJ/m^2 year of EU countries, which will be discussed in Section 6.10.1.



N. Cyprus	103
Slovakia	119
Czech Rep.	98
Poland	88
Italy	90
Portugal	83
Spain	180
France	93
Belgium	130
Netherland	88
Germany	83
Sweden	52
Denmark	60
Norway	76
Finland	121
Switzerland	87
Austria	133
Uk	83
Ireland	67
Greece	79
Turkey	69

Figure 6.28: Energy Loss Through Walls per Country, 2001 (MJ/m^2 year).

6.9 Estimation of Energy Loss Through Roofs of Houses in North Cyprus

Table 6.34 shows the heat loss calculations per unit area of typical roof with and without insulation. The overall heat transfer coefficient are also as it is given in Table 6.14

Table 6.35: Determination of Heat Loss Through Roofs with/without Insulation.

Building Comp.		Heat Loss Calculations		
	Area per Unit Area	Heat Tr. Coeff.	Temp. Diff.	Heat Loss per unit area
		k	T	Qo
	m^2/m^2	$W/m^2 {}^oC$	^oC	W/m^2
Concrete Roof with No Insulation	1.00	2.00	1	2.00
Concrete Roof with insulation	1.00	0.57	1	0.57

Energy loss per year for insulated and non insulated roofs are calculated and presented in Tables 6.35, with a similar methodology to Table 6.27. By including the distribution of roof types in North Cyprus, energy loss per meter square per year of an average roof can be determined and presented in Table 6.37.

Table 6.36: Determination of Energy Loss per Year Through Roofs without Insulation in North Cyprus.

	Heat Loss ($W/^oC$)	Room Temp. (^oC)	Outside Temp. (^oC)	Temp. Different (^oC)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
RI	2.0						
Nov.		22	9.9	12.1	24.20	0.70	20.91
Dec.			6.8	15.2	30.40	0.88	26.27
Jan.			5.4	16.6	33.20	0.96	28.68
Feb.			5.5	16.5	33.00	0.95	28.51
Mar.			7.0	15.0	30.00	0.86	25.92
Apr.			10.4	11.6	23.20	0.67	20.04
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							150.34
TOTAL Heat Loss per m^2 (Heating)							76.67

Table 6.37: Determination of Energy Loss per Year Through Roofs with Insulation in North Cyprus.

	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
R	0.6						
Nov.		22	9.9	12.1	7.26	0.21	6.27
Dec.			6.8	15.2	9.12	0.26	7.88
Jan.			5.4	16.6	9.96	0.29	8.61
Feb.			5.5	16.5	9.90	0.29	8.55
Mar.			7.0	15.0	9.00	0.26	7.78
Apr.			10.4	11.6	6.96	0.20	6.01
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							45.10
TOTAL Heat Loss per m^2 (Heating)							23.00

Table 6.38: Total Determination of Energy Loss per Year in Roof with or with out Insulation in North Cyprus.

Roof Type	No. of Houses	Percentages of Houses	Energy loss per m^2	Energy Loss by %
R	26	11.26%	150.34	16.92094
RI	205	88.74%	45.10	40.02452
	231	100.00%		56.94545

N. Cyprus	57
Slovakia	78
Czech Rep.	78
Poland	88
Italy	156
Portugal	69

Figure 6.29 represents the situation of North Cyprus among EU countries. Unlike total energy loss per year per country, energy loss through roofs of North Cyprus per meter square is higher 57 MJ/m^2 per year), when compared with the other countries because of poor insulation. The roofs must be insulated with to drop this value to the required level of 35 MJ/m^2 year of EU countries, which will be discussed in Section 6.10.2.

Spain	124
France	58
Belgium	130
Netherland	88
Germany	40
Sweden	35
Denmark	40
Norway	52
Finland	95
Switzerland	81
Austria	73
Uk	38
Ireland	27
Greece	53
Turkey	43

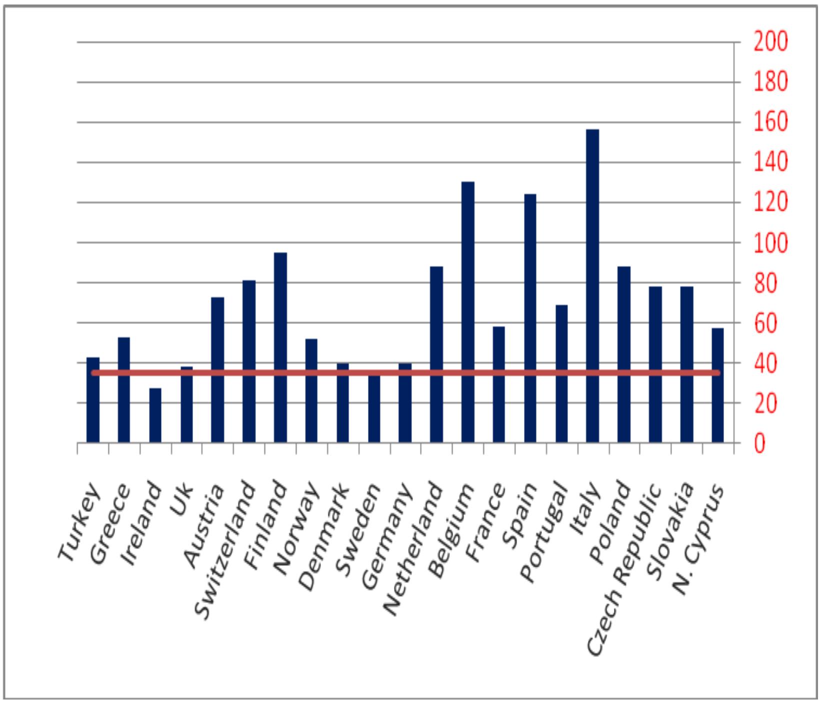


Figure 6.29: Energy loss through roofs per country, (MJ/m^2 year).

6.10 Determination of Insulation Requirements for North Cyprus

6.10.1 Determination of Insulation Requirements for Walls

Building materials for wall in North Cyprus are terracotta bricks and concrete blocks. Terracotta bricks must be insulated to obtain the standards of EU. In this section terracotta bricks walls with insulation thickness 3.0, 3.5, 4.0, and 5.0 cm and concrete blocks without insulation were examined as shown in Tables 6.38 to 6.43 with a similar methodology as in the previous sections. Although, generally insulation to the roofs is very rear in North Cyprus, insulation thickness used is 5 cm. This thickness gives less energy loss that required. It was determined that 3 cm of insulation on walls will give an average loss of 52.62 MJ/m^2 year, which is acceptable according to EU standards.

Using concrete blocks requires no insulation, since it gives 51.83 MJ/m^2 year, which is also acceptable to EU standards. Table 6.44 and Figure 6.30 summarize the results obtained for walls.

Table 6.39: The Heat Loss Through Insulated Walls with Different Thickness Insulation**.**

Building Comp.		Heat Loss Calculations		
	Area per Unit Area	Heat Tr. Coeff.	Temp. Diff.	Heat Loss per unit area
		k	T	Qo
	m^2/m^2	W/m^2 ^{o}C	^{o}C	W/ m^2
P-TB-I-P thickness: 3.0 cm	1.00	0.70	1	0.70
P-TB-I-P thickness: 3.5 cm	1.00	0.64	1	0.64
P-TB-I-P thickness: 4.0 cm	1.00	0.60	1	0.60
P-TB-I-P thickness: 5.0 cm	1.00	0.50	1	0.50

Table 6.40: Determination of Energy Loss per Year in P-TB-I-P with Thickness 3.0cm.

P-TB-I-P	3 cm						
	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	0.70						
Nov.		22	9.9	12.1	8.47	0.24	7.32
Dec.			6.8	15.2	10.64	0.31	9.19
Jan.			5.4	16.6	11.62	0.33	10.04
Feb.			5.5	16.5	11.55	0.33	9.98
Mar.			7.0	15.0	10.50	0.30	9.07
Apr.			10.4	11.6	8.12	0.23	7.02
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							52.62
TOTAL Heat Loss per m^2 (Heating)							26.83

Table 6.41: Determination of Energy Loss per Year in P-TB-I-P with Thickness 3.5cm.

P-TB-I-P	3.5 cm						
	Heat Loss	Room Temp.	Outside Temp.	Temp. Different	Heat Loss	Daily Heat	Monthly (MJ)

	(W/°C)	(°C)	(°C)	(°C)	(W)	Loss (MJ)	
	0.64						
Nov.		22	9.9	12.1	7.74	0.22	6.69
Dec.			6.8	15.2	9.73	0.28	8.40
Jan.			5.4	16.6	10.62	0.31	9.18
Feb.			5.5	16.5	10.56	0.30	9.12
Mar.			7.0	15.0	9.60	0.28	8.29
Apr.			10.4	11.6	7.42	0.21	6.41
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							48.11
TOTAL Heat Loss per m^2 (Heating)							24.53

Table 6.42: Determination of Energy Loss per Year in P-TB-I-P with Thickness 4.0cm.

P-TB-I-P	4 cm						
	Heat Loss (W/°C)	Room Temp. (°C)	Outside Temp. (°C)	Temp. Different (°C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	0.60						
Nov.		22	9.9	12.1	7.26	0.21	6.27
Dec.			6.8	15.2	9.12	0.26	7.88
Jan.			5.4	16.6	9.96	0.29	8.61
Feb.			5.5	16.5	9.90	0.29	8.55
Mar.			7.0	15.0	9.00	0.26	7.78
Apr.			10.4	11.6	6.96	0.20	6.01
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							45.10
TOTAL Heat Loss per m^2 (Heating)							23.00

Table 6.43: Determination of Energy Loss per Year in P-TB-I-P with Thickness 5.0cm.

P-TB-I-P	5 cm						
	Heat Loss (W/°C)	Room Temp. (°C)	Outside Temp. (°C)	Temp. Different (°C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	0.50						
Nov.		22	9.9	12.1	6.05	0.17	5.23
Dec.			6.8	15.2	7.60	0.22	6.57
Jan.			5.4	16.6	8.30	0.24	7.17
Feb.			5.5	16.5	8.25	0.24	7.13
Mar.			7.0	15.0	7.50	0.22	6.48
Apr.			10.4	11.6	5.80	0.17	5.01
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							37.58
TOTAL Heat Loss per m^2 (Heating)							19.17

Table 6.44: Determination of Energy Loss per Year in P-CB-P with out Insulation**.**

P-CB-P							
	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	0.69						
Nov.		22	9.9	12.1	8.35	0.24	7.21
Dec.			6.8	15.2	10.49	0.30	9.06
Jan.			5.4	16.6	11.45	0.33	9.90
Feb.			5.5	16.5	11.39	0.33	9.84
Mar.			7.0	15.0	10.35	0.30	8.94
Apr.			10.4	11.6	8.00	0.23	6.92
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							51.87
TOTAL Heat Loss per m^2 (Heating)							26.45

Table 6.45: Total Energy Loss per m^2 in Different Wall Types.

Wall Type	Thickness (cm)	TOTAL Energy Loss per m^2
PTBIP	TB-I 3.0 cm	52.62
PTBIP	TB-I 3.5 cm	48.11
PTBIP	TB-I 4.0 cm	45.10
PTBIP	TB-I 5.0 cm	37.58
PTBP	TB-I 0.0 cm	112.75
PCBP	CB	51.87

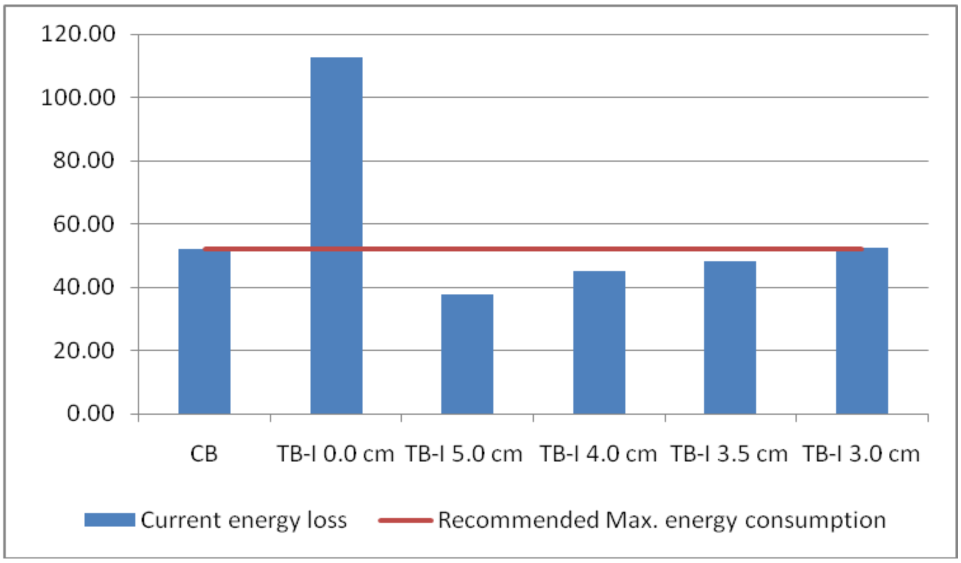


Figure 6.30: Situation of Walls According to EU Standards in Terms of Heat Loss.

6.10.2 Determination of Insulation Requirement for Roofs

Similar work was done for roofs with insulation thickness 5.0, 6.0, 6.5, and 7.0 cm. It was obtained that 7 cm will give an average loss of 35 MJ/m^2 year, which is acceptable according to EU standards, Table 6.51 and Figure 6.31 summarize the results obtained for roofs.

Table 6.46: The Heat Loss Through Insulated Roofs with Different Thickness Insulation**.**

Building Comp.		Heat Loss Calculations		
	Area per Unit Area	Heat Tr. Coeff.	Temp. Diff.	Heat Loss per unit area
		k	T	Qo
	m^2/m^2	$W/m^2 \,^oC$	^oC	W/m^2
CB	1.00	2.00	1	2.00
P-CB-I-P thickness: 5.0 cm	1.00	0.57	1	0.57
P-CB-I-P thickness: 6.0 cm	1.00	0.50	1	0.50
P-CB-I-P thickness: 6.5 cm	1.00	0.47	1	0.47
P-CB-I-P thickness: 7.0 cm	1.00	0.44	1	0.44

Table 6.47: Determination of Energy Loss per Year of Roofs with 5.0 cm Thickness Insulation**.**

RI		5.0 cm					
	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	0.57						
Nov.		22	9.9	12.1	6.90	0.20	5.96
Dec.			6.8	15.2	8.66	0.25	7.49
Jan.			5.4	16.6	9.46	0.27	8.18
Feb.			5.5	16.5	9.41	0.27	8.13
Mar.			7.0	15.0	8.55	0.25	7.39
Apr.			10.4	11.6	6.61	0.19	5.71
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							42.85

Table 6.48: Determination of Energy Loss per Year of Roof with 6.0 cm Thickness Insulation**.**

RI		6.0 cm					
	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	0.50						
Nov.		22	9.9	12.1	6.05	0.17	5.23
Dec.			6.8	15.2	7.60	0.22	6.57
Jan.			5.4	16.6	8.30	0.24	7.17
Feb.			5.5	16.5	8.25	0.24	7.13
Mar.			7.0	15.0	7.50	0.22	6.48
Apr.			10.4	11.6	5.80	0.17	5.01
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							37.58

Table 6.49: Determination of Energy Loss per Year of Roof with 6.5 cm Thickness Insulation**.**

RI		6.5 cm					
	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	0.47						
Nov.		22	9.9	12.1	5.69	0.16	4.91
Dec.			6.8	15.2	7.14	0.21	6.17
Jan.			5.4	16.6	7.80	0.22	6.74
Feb.			5.5	16.5	7.76	0.22	6.70
Mar.			7.0	15.0	7.05	0.20	6.09
Apr.			10.4	11.6	5.45	0.16	4.71
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							35.33

Table 6.50: Determination of Energy Loss per Year of Roof with 7.0 cm Thickness Insulation**.**

RI		7.0 cm					
	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	0.44						
Nov.		22	9.9	12.1	5.32	0.15	4.60
Dec.			6.8	15.2	6.69	0.19	5.78
Jan.			5.4	16.6	7.30	0.21	6.31
Feb.			5.5	16.5	7.26	0.21	6.27
Mar.			7.0	15.0	6.60	0.19	5.70
Apr.			10.4	11.6	5.10	0.15	4.41
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							33.07

Table 6.51: Determination of Energy Loss per Year of Roof with 0.0 cm Thickness Insulation**.**

R		0.0 cm					
	Heat Loss (W/^{o}C)	Room Temp. (^{o}C)	Outside Temp. (^{o}C)	Temp. Different (^{o}C)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	2.0						
Nov.		22	9.9	12.1	24.20	0.70	20.91
Dec.			6.8	15.2	30.40	0.88	26.27
Jan.			5.4	16.6	33.20	0.96	28.68
Feb.			5.5	16.5	33.00	0.95	28.51
Mar.			7.0	15.0	30.00	0.86	25.92
Apr.			10.4	11.6	23.20	0.67	20.04
TOTAL Heat Loss per m^2 (Central Heating) (MJ)							150.34

Table 6.52: Total Energy Loss for Different Insulation Thicknesses of Roofs.

Roof Type	Insulation Thickness	energy loss
R	0.0 cm	54.94
RI	5.0 cm	42.85
RI	6.0 cm	37.58
RI	6.5 cm	33.07
RI	7.0 cm	35.33

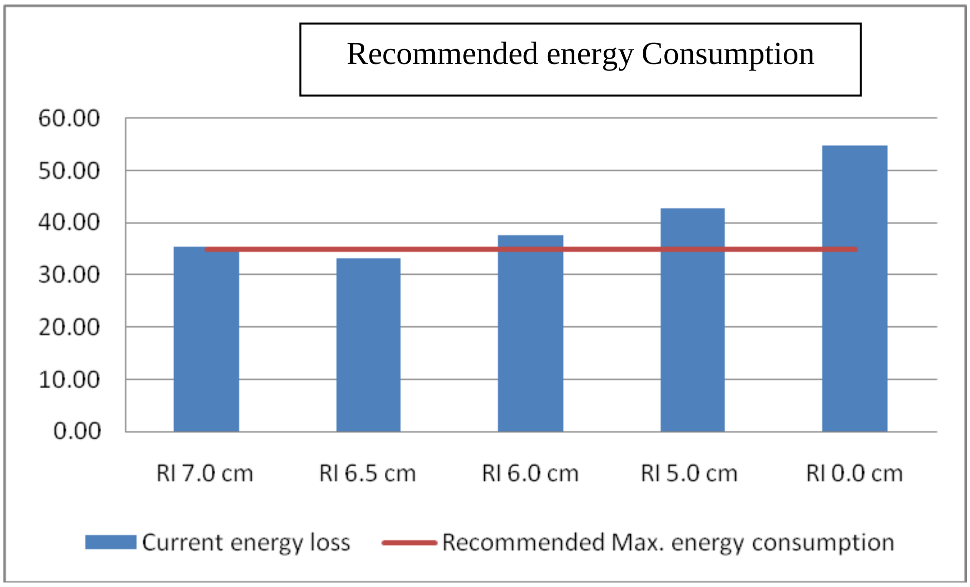


Figure 6.31: Situation of Roofs According to EU Standards in Terms of Heat Loss.

6.11 Estimation of Energy Loss of Houses According to EU Standards

In this section the energy loss of North Cyprus will be estimated if the houses were built according to EU standards. 3 cm and 7 cm of insulation were considered for walls and roofs, respectively but floors were not insulated. Double glazed PVC windows were also assumed in buildings. Instead of 3 cm wall insulation, using concrete blocks with out insulation will give the same results.

In Table 6.52 heat loss per unit area per degrees centigrade for detached and semi-detached houses and flats, in Table 6.53 total energy loss per degrees centigrade of an average house and in Table 6.54 energy loss per year in North Cyprus were estimated. Energy loss will drop to 2601 million MJ. If the results of recent energy loss, which is 4881 million MJ, and the energy loss that would be if EU standards were applied to the houses were compared it can be seen that there will be about 2700 million MJ (about 50%) energy saving in North Cyprus only due to insulation of walls and roofs and double glazed PVC windows.

Table 6.53: Determination of Heat Loss of Houses per m^2 per ^{o}C in Detached and Semi-Detached Houses, and Flats.

Building Comp.		Heat Loss Calculations			Infiltration						
	Area per Unit Area	Heat Tr. Coeff.	Temp. Diff.	Heat Loss per unit area	Infiltration coefficient	Periphery	Room Coefficient	Building Coefficient		Heat for Infiltration	Total Heat Loss per unit area
		K	T	Qo	a	I	R	H	Ze	Qs	Q
	m^2 /m^2	**W/m^2 ^{o}C**	**^{o}C**	**W/m^2**		**m/m^2**				**W/ m^2**	**W/ m^2**
D											
P-TB-I-P	0.92	0.5	1	0.64							
DG-PVC	0.24	3.0	1	0.72	1	0.38	0.9	2.43	1.2	0.499	
CR-I	1.00	0.6	1	0.44							
CF-NI	1.00	2.3	0.5	1.13							
TOTAL				**2.94**						**0.499**	**3.21**
SD											
P-TB-I-P	0.92	0.5	1	0.67							
DG-PVC	0.24	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.499	
CR-I	1.00	0.6	1	0.44							
CF-NI	1.00	2.3	0.5	1.13							
TOTAL	**3.17**			**2.90**						**0.499**	**4.75**
F											
P-TB-I-P	0.92	0.5	1	0.57							
DG-PVC	0.24	3.0	1	0.66	1	0.38	0.9	2.43	1.2	0.499	
CR-I	1.00	0.6	1	0.44							
CF-NI	1.00	2.3	0.5	1.13							
TOTAL	**3.04**			**2.81**						**0.499**	**3.43**

Table 6.54: Total Energy Loss per ^{o}C of an Average House in North Cyprus.

Type	Total Heat Loss Per Unit Area	Percentages %	Average Area of house types	Average heat loss of houses per ^{o}C in North Cyprus (W/ ^{o}C)
D	3.43	53	135	245.42
SD	3.39	5	130	22.03
F	3.30	42	140	194.04
Total				461.49

Table 6.55: Estimation of Heat Loss per Year in North Cyprus.

	Heat Loss ($W/^oC$)	Room Temp. (^oC)	Outside Temp. (^oC)	Temp. Different (^oC)	Heat Loss (W)	Daily Heat Loss (MJ)	Monthly (MJ)
	461.5						
Nov.		22	9.9	12.1	5584.05	160.82	4824.62
Dec.			6.8	15.2	7014.67	202.02	6060.68
Jan.			5.4	16.6	7660.76	220.63	6618.90
Feb.			5.5	16.5	7614.61	219.30	6579.02
Mar.			7.0	15.0	6922.37	199.36	5980.93
Apr.			10.4	11.6	5353.30	154.18	4625.25
TOTAL Heat Loss per house (Central Heating) (MJ)							34689.39
TOTAL Heat Loss per house (Heating)							17691.59
TOTAL Energy Loss in North Cyprus (million MJ)							2601.70

7. CONCLUSIONS

Fossil fuels are the main source of energy on earth and the reserves are decreasing every day. Being the main source of energy, fossil fuels are also one of the main causes of carbon dioxide emission to the atmosphere, increasing the greenhouse effect resulting in global warming which is one of the most important threats on earth. People are trying to find ways for effective usage of alternative energy resources which are clean and will exist as long as the earth exists. It is important to decrease the energy usage to extent the time period for fossil fuels and to decrease the global warming.

As an example, 57 % of energy is used for space heating in European Countries. Better architecture and energy savings in buildings could do more to save energy and fight global warming on greenhouse gases agreed under the U.N.'s Kyoto Protocol. Studies are continuing all over the world. The aim of this study is to investigate the situation of houses in North Cyprus in this extent, to estimate and compare the amount of energy used for space heating with European standards and countries, to determine required insulations for houses according to European standards and to estimate the amount of energy that will be saved if all the houses are constructed accordingly.

Among the earth's climate zones, North Cyprus is in the Mediterranean Climate Zone with long warm and dry summers from mid-May to mid-October and mild and wet winters from December to February. The short autumn and spring periods complete the seasons of the year. In winter, temperatures rarely drop below 5°C and are more likely to be in the region of 12° to 13°C while in summer averages can be up to 27°C. Frosts are very rare but there are unpleasent winds. According to these climatic conditions not much energy for heating and cooling is required if proper insulation is done for heat loss, heat gain and inflitration.

However, it was observed from the results of the questionnaire conducted among 231 participants within the content of this study that 94% of houses have no insulation on walls and 89% on roofs. These results can be considered to be the first estimates on the amount of energy wasted in heating and cooling applications. To estimate these amount

67 architectural plans were examined together with the results obtained from the questionnaire and the general characteristics of the houses were determined.

In North Cyprus, there are three main types of houses, namely, detached semi-detached and flats with 53%, 5% and 42%, respectively. 3.5 people are living in each house on average and according to the population of 265100 people there are about 75000 houses in active usage. These results of the questionnaire, including others like distribution of population, were compared with national population and house census in 2006 of TRNC-Pry Ministry Governmental Office of Planning and it was observed that they are in good agreement.

According to the questionnaire and architectural plans, average size of an house is 135 m^2, changing about 3% according to the type, 92% of the houses are constructed from terracotta brick and remaining from concrete blocks, 78% of houses have aluminum windows which is not a proper choice in terms of heat loss and infiltration, only 15% of the houses have double glazed windows but improved to 46% in the last five years, 64% of the houses have flat concrete roofs, only 2% of houses are using central heating while the remaining are using local heating by heaters and air-conditioners with 53% and 45%, respectively.

Analyzing the data obtained energy losses through walls and roofs per square meter per year were estimated to be 103 MJ/m^2 year and 57 MJ/m^2 year, respectively, in North Cyprus. These values are 98 % and 63 % more than European recommended values of 52 MJ/m^2 year and 35 MJ/m^2 year, respectively. Total energy loss per year for North Cyprus was estimated to be 5305 MJ/year which is only 0.1 % of the European total. It was determined that 3 cm and 7 cm of polystyrene or glass wool insulation for terracotta bricks terracotta brick walls and concrete roofs, respectively, and double glazed windows will be enough to reduce the heat losses to European standards and will reduce the total energy loss per year by about 50 %. No insulation for floor is considered because of the difficulties that will arise due to construction methods that are used in North Cyprus. If concrete blocks are used instead of terracotta bricks no additional insulation material will be required.

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