Comparison of Radiator and Under Floor Heating Systems in North Cyprus

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ABSTRACT

The main objective of the present study is to investigate the differences between the heating technologies and propose the ones suitable for North Cyprus.

Nowadays, mostly used heating systems are to provide people using the space with comfortable and clean inner-space air with an acceptable quality. The main objective in space with artificial heating is to enable people to live in hygienic and comfortable living spaces at minimum energy cost.

The performance of the heating system in terms of thermal comfort and energy efficiency are the determining factors in choosing such systems. Climate conditions, the space heating mechanism of the system, fuel type, usage type and function of the space, the thermal isolation features of the space are the variables affecting the performance of the heating system.

The present study compares the radiator heating systems with the underfloor heating systems in terms of energy efficiency, thermal comfort and application techniques. As a result of the literature review and the calculations, when the radiator heating systems are compared with underfloor heating systems; it was concluded that the underfloor heating systems are the most appropriate heating system for the human thermal-physiological needs. Law of physics proves that the uniform heat most suitable for human anatomy rises from ground surfaces. Underfloor heating systems are the most ideal for human thermal comfort as the heat rise from the ground. Underfloor heating systems are the systems that use energy most efficienctly and economically when applied with heat pump and renewable energy resources; as well as energy efficiency due to their low-temperature fluid heat. It was also concluded that, with the right application techniques, the most durable heating system is the underfloor heating.

Keywords: Thermal comfort, energy efficiency, application technique, renewable energy, radiator heating system, underfloor heating system.

ÖZ

Bu çalışmanın temel amacı ısıtma teknolojilerini karşılaştırmak ve bunun sonucunda Kuzey Kıbrıs şartları için en uygun olanları önermektir.

Günümüzde yaygın olarak kullanılan ısıtma sistemlerinin amacı; bu ortamı kullanan insanlara kabul edilebilir kalitede konforlu ve temiz iç ortam havası oluşturmaktır. Yapay olarak ısıtılmış hacimlerde asıl amaç, minimum enerji harcayarak bu hacimleri kullanan kişiler için, hijyenik ve konforlu yaşam alanları sağlamaktır.

Isıtma sisteminin ısıl konfor ve enerji korunumu açısından performansı, seçim yapılırken belirleyici faktörlerdir. İklim koşulları, sistemin mekanı ısıtma mekanizası, yakıt türü, mekanın kullanım şekli ve fonksiyonu, mekanın ısı yalıtım özelliği, ısıtma sisteminin performansını etkileyen değişkenlerdir.

Bu çalışmada, radyatörlü ısıtma sistemleri ile yerden ısıtma sistemleri, enerji korunumu, ısıl konfor ve uygulama yöntemleri yönünden karşılaştırılmıştır. Yapılan literatür taramaları ve hesaplamalar sonucunda radyatörlü ısıtma sistemeleriyle yerden ısıtma sistemleri karşılaştırldığında; insan ısısal-fizyolojik ihtiyaçlarına en uygun ısıtma sisteminin yerden ısıtma olduğu sonucuna varılmıştır. Fizik kuralları insan anatomisine uygun uniform ısının taban zeminlerinden yükseldiğini ıspatlamaktadır. Yerden ısıtma sistemlerinde ısı zeminden yükseldiğinden insan ısısal konforu için en ideal ısıtma sistemidir. Yerden ısıtma sistemleri düşük akışkan sıcaklıkları sayesinde enerji tasarrufu sağlarken, Isı pompası ve yenilenebilir enerji kaynaklarıyla birlikte uygulandığında enerjiyi en verimli ve en ekonomik kullanan ısıtma sistemidir. Doğru yapılacak olan uygulama sayesinde en uzun ömürlü ısıtma sisteminin yerden ısıtma olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Isıl konfor, enerji verimliliği, uygulama teknikleri, radiatörlü ısıtma sistemi, yerden ısıtma sistemi.

To My Beloved Family

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TABLE OF CONTENTS

ABSTRACT……………………………………………….………………….……..iii

ÖZ………………………………………………….…………………………….....v

DEDICATION…………………………………..…………………………......vii

ACKNOWLEDGMENT…………………………………….……………….........vi

LIST OF TABLES……………………………………..……………………......xi

LIST OF FIGURES……………………………………..………………......xiii

LIST OF SYMBOLS/ABBREVIATIONS……………..…………………….........xvi

1 INTRODUCTION………………………..……………………………………...1

1.1 Introduction……………..…………………………………………..…..1

1.2 Aim of the Research and Methodology …..……….……………………….…....3

1.3 Problem Statement …………………………………………………..……....4

1.4 Limitation of the Study…………………………………………….……...4

1.5 Literature Review……………………………………………………….…..…5

2 THEORETICAL BACKGROUND…….…………………………………….……….9

2.1 Thermal Comfort……………………..……………………………….……..9

2.2 Description of the Heating Systems……………….……..………………….....17

2.2.1 Central Heating Radiator System….……………………………………..…18

2.2.2 Central Heating Underfloor Heating System……………………………......20

2.2.3 Central Heating Heat Pump System………………………………………25

2.3 Relation Between Heating Systems and Thermal Comfort…………………..26

2.4 Energy Efficiency of Heating System……………………………………..28

2.4.1 Investment Cost……………………………………….……………..29

2.4.2 Annua Energy Cost……………………………………………….......30

2.5 Application Techniques of Heating System…………………………………......30

2.5.1 Floorcovering…………………………………………………………….....33

2.5.2 Mainenance and Operation MCO Cost(annual)…………………………....37

2.6 Renawable Energy use in Heating System…………………………………....38

3 EVALUATION OF THE HEATING SYSTEM IN TERMS OF THERMAL COMFORT, ENERGY EFFICENGY AND APPLICATION TECHNIQUES…..42

3.1 Evaluation of the Heating System in Terms of Thermal Comfort…………......42

3.2 Evaluation of the Heating System in Terms of Energy Efficiency…………....47

3.3 Evaluation of the Heating System in Terms of Application Techniques..……68

4 CONCLUSION……………………………………………………………...….74

REFERENCES…………………………………………………………...…80

LIST OF TABLES

Table 1: ASHRAE Thermal sensation scale…………………………………….........16

Table 2. Flooring materials for floor heating and their features…………………….....36

Tablo 3. Radiator heating and floor heating systems with solar energy…………….....40

Tablo 4: Investment cost for panel radiator system..49

Tablo 5 : Investment cost for floor heating system..49

Table 6: COP values for hot water panel radiator and hot water floor heating System...51

Table 7: Average operation productivity COP values, lower heating values of fuel types, fuel unit cost for radiator systems……….……...……………………..…......51

Table 8: Average operation productivity COP values, lower heating values of fuel types, fuel unit cost for floor heating systems...........……………….……..................52

Table 9: Daily energy costs of a panel radiator 100 m² residence thermal insulation……………......…………………………………………………………..54

Tablo 10: Daily energy cost floor heating system 100 m² residance with thermal insulation...57

Table 11: The annual operation cost of panel radiator system…..……......……......58

Tablo 12: The annual operation cost of panel radiator system………...……...…...58

Table 13: The annual operation cost of floor heating System………………….......59

Table 14: The annual operation cost of floor heating System……………………....59

Table 15: The energy efficiency rate of 100 m² residence with and without thermal insulation ……………….........……………………………………………………......62

Table 16: Parameters………………………………………………………......79

LIST OF FIGURES

Figure 1: The rate of metabolic generation may go up six times the resting level during total body shivering in cold weather..11

Figure 2: Thermal balance of human body...12

Figure 3: Machanisms of heat loss from the human body and realive magnifudes for a resting person..12

Figure 4: Cloting serves as insulation and the room temperature needs to be raised when person is unclothed to maintain the same comfort level..................................14

Figure 5: Cold surfaces cause excessive heat loss from the body by radiation, and thus discomfort on the side of the body.……………………………………………15

Figure 6: Relation between predicted percentage of dissatisfied (PPD) and Predicted mean vote (PMV)……………….………………………………….…………..........16

Figure 7:Sectional cast-iron radiator……………………………...…...…………19

Figure 8: Steel panel radiator…………….……………..…………………………...19

Figure 9: Sectional aluminum radiator ………………………..………………….....20

Figure 10: Underfloor heating system application………………………..……...21

Figure 11: Radiant underfloor heating system……….……………......................22

Figure 12: Detail of radiant underfloor heating system……………………………..22

Figure 13: Watered underfloor heating system…………………….....................23

Figure 14: Detail of watered underfloor heating system……………………........23

Figure 15: Infrared underfloor heating system………………………………........24

Figure 16: Detail of infrared underfloor heating system…………………………....24

Figure 17: Schematic Diagram of a Compression Heat Pump.……...………….......25

Figure 18: Diagram of a radiator heated room with heat distribution.......................27

Figure 19: Diagram of a under floor heated room with heat distribution..................27

Figure 20: Radiator system application……………………………….………31

Figure 21: Radiator collector details……………………………...…………...….31

Figure 22: Cooper-pipe radiator connection……………………………...........32

Figure 23: Plastic-pipe radiator connection……………………………….………...32

Figure 24: Underfloor heating system application section.......................................33

Figure 25: Laminate flooring details …………………………………........…...34

Figure 26: Installing underfloor heating under laminate…………………..……..34

Figure 27: Installing underfloor heating under carpet ….………………………..…35

Figure 28: Stone, ceramic or marble tiles flooring details..………….....……….…....35

Figure 29: Installing underfloor heating under stone and ceramic tile..………...….36

Figure 30: Installing underfloor heating under marble....………………….………36

Figure 31: Space Heating with Solar Energy…………………...………………...39

Figure 32: Geothermal heating system……..41

Figure 33: The heat distribution profile. As the above drawing shows, floor heating is the ideal floor heating...42

Figure 34: Diagram of a radiator heated room with heat distribution........................43

Figure 35: Diagram of a underfloor heated room with heat distribution....................44

Figure 36: Radiator and underfloor heating diagram...46

Figure 37: 85 °C Dimension of Panel Radiator...48

Figure 38: 60 °C Dimension of Panel Radiator...48

Figure 39: The Figure Demonstrates how the COP Performance Value of the Heat Pump is Calculate..67

Figure 40: Radiator System Application...69

Figure 41: Radiator Wall with and withouth Insulation..69

Figure 42: Radiator System Correct Application…………………………………....71

Figure 43: Radiator System Wrong application……………………..……………......71

Figure 44: Floor Heating Application Detail…………..……………………….........72

LIST OF SYMBOLS/ABBREVIATIONS

PPD	Relation between Predicted Percentage of Dissatisfied
ASHREA	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ISO	International Organization for Standardization
°C	Centigrade Degrees
Clo	Cloting
LPG	Liquid Petroleum Gas
C.O.P	Coefficient of Performance
Cm	Centimeter
ɳ	Efficiency(used for boilers)
kw	Kilowatt
m^2	Square meters
kcal/h	Kilowatt hour
€	Euro
LPG	Gas oil

Chapter 1

INTRODUCTION

1.1 Introduction

The need for heating has originated from the necessity to create a temperature change balance between the human body and the environment; and the need to provide a thermal comfort setting. Heating is, now a natural comfort factor for us. People demand the best thermal comfort in the buildings they live in. The comfort conditions should be at the optimum standards at all times of the day and in all part of the house. These comfort conditions are provided with the aid of the heating systems.

The performance of the heating systems in terms of thermal comfort and energy efficiency are the determining factors in choosing heating systems. Climate conditions, the space heating mechanism of the system, fuel type, usage type and function of the space, the thermal isolation features of the space are the variables affecting the performance of the heating system.

The present study, firstly, focused on the thermal comfort, energy efficiency and application techniques used for building heating systems.

Radiator heating systems and underfloor heating systems were compared as a result of the literature review. The results of the comparison showed that the most suitable heating system for human thermal-physiological needs is the underfloor heating system. All creatures on earth live healthily at 23-25°C temperatures and the average floor temperature for a health human being is 25°C. Physically, this uniform temperature can only be attained through floor heating. The boiler water fluid regime used for underfloor heating is 45-50°C. The water running in the system is warm water at 30°C, and the felt temperature coming to the flooring surface is 25°C (Anonim, 2003).

Another feature that distinguishes underfloor heating systems from radiator heating systems is the different temperature of water needed for heating. The water temperature needed from the heater supplier is 70 – 90ºC in radiator heating systems; whereas, due to the wide heating surface of the underfloor heating systems these temperature level at about 40 – 50ºC depending on the heating need of the building. It was concluded that: as the water fluid running in the underfloor heating systems are at lower temperatures than the radiator heating systems; they allow energy efficency and significantly reduce operation costs; as the fluid temperature is lower than radiator heating systems, underfloor heating can also considerably reduce investment costs with the correct design using the renewable energy resources; and that underfloor heating systems are the most durable heating systems with the correct application.

1.2 Aim of the Research and Methodology

The present study is to evaluate the radiator heating and underfloor heating systems used for house-heating in terms of thermal comfort, energy efficiency (cost analysis) and application techniques; and conclude which system is the most ideal for house-heating. The results of these evaluations include stating the factors affecting thermal comfort, energy efficiency and application techniques; and suggestions for operating the systems more efficiently.

The method followed in the present study was formed as follows. The topic of the study was evaluated from the thermal comfort, energy efficiency and application techniques aspects in detail through the literature review and the data collected from the Union of the Chambers of Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers. The result on which heating system is the best for thermal comfort conditions to meet the heating needs is determined after the evaluations on the heat transfer between human and the heating system and the surrounding environment.

The tables used in the energy and cost analysis are designed based on the date collected from The Union of the Chambers of Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers. In the light of these data, which system has the most suitable cost is concluded.

The evaluated systems are:

- Central Heating Radiator Systems
- Central Underfloor Heating Systems

The literature was also reviewed on how to use these systems. After considering the evaluations on thermal comfort, energy efficiency (cost) and application techniques, the method of the present study was formed to suggest the most suitable system.

1.3 Problem Statement

The heating systems used in houses do not provide the correct results because of application and operation flaws. Operation of these systems at high temperatures and discontinuous use of them result in increased use of heating energy, thermal discomfort, health problems and building damages.

Therefore, the present study will provide suggestions for the correct application of the heating systems used in houses by the companies and at which values should the users operate the systems.

1.4 Limitation of the Study

Limitation of the present study is based on research of usage of heating systems today in literature and investigation in terms of thermal comfort, energy efficiency, in terms of the application techniques.

1.5 Literature Review

There are a lot of works about heating from coverings in literature:

Chen and Athienitis, in underfloor heating systems from floor covering, examined transition conditions of heat transfer as three-dimensional with explicit ending difference method. The study was focused on floor covering and solar radiation falling on it (Chen, 2000).

Olesen's experimental comparative study compared the heating performance of wall and flooring panels. The effect of specific dynamic factors such as solar radiation entering through windows, external temperature changes, lighting and heat released by people were also considered within the study. Results indicated that thermal comfort could be secured in both panel installations. Additionally, the study indicated that the energy use of both systems were at the same level (Olesen, 1994).

Zmeureanu, examined a house near Montreal in situations of being heated by hot water and by air, and additionally calculated the lifetime energy use for both situations. After comparing the results of both calculations, it was found that heating with hot water would be more beneficial. Information on the structure of the house and installment equipment can also be found within the study (Zmeureanu, 2008). .

Int-Hout has done works to change the system parameters that provide comfort and renable energy savings. With using low temperature air in heating systems, comfort conditions and desired level air are provided. In addition to these, it has been shown that both management and investment costs have (Int-Hout, 1992).

Fanger and his friends analysed the lack of satisfaction of people according to temperature, humidity and skin wetness in their studies. In this study, it is recommended that humidity should be kept under %36 for 26°C, %57 for 23°C. In addition to this, it has been mentioned about negative effects of low and high humidity for people’s health and building elements (Fanger, 1999).

Chapman, while radiation on the radiant panel is not a normal function, it has been seen that convection is highly related to this factor. For example; when a panel installed to the ceiling releasing heat downwards and a panel installed to the ground, releasing heat upwards are compared in terms of convection, there are large differences; but when all the other parameters are kept the same, no difference in the heat transfer can be found in terms of radiation. For this reason, the radiation heat transfers rate to total heat transfer for different panel orientations can change (Chapman, 2004).

Yiğit and colleagues examined the effects of the change of parameters that was give for continuous regime energy model the energy be in a, equations of heat transfer between the body and the environment and expresses the thermal comfort and physiological control mechanisms in the body the effects, by taking advantage empiric correlation, the effects of the change of parameters such asthe conditions that affect people's thermal comfort temperature, relative humidity, air velocity, metabolic activity, and insulation resistance of clothes. ASHRAE Standard 55-92's given, in order to qualify as a comfotable environment PPD value 10% should not exceed 10% and the criterion taking into account for people to feel comfortable under different circumstances they came up with thermal comfort zones and presented in graphs (Yiğit, 2003).

Athienitis shows that the material used in floor heating systems can store the heat both from heating panels and from the solar heat coming in through the windows. Due to this reason, the temperature of the floor surface can sometimes exceed the thermal comfort temperature. With the condition of providing thermal comfort, studies which aim to develop a control mechanism to decrease energy in different weather conditions, have been conducted. A study resulted in a more economic way by considering the solar heat which is collected by radiation and the maximum temperature of the surface (Athientis, 1994).

Teke and Karadağ, in their works, they used two methods investigate the relationship between radiation of a room by heating from coverings and heating transfer matris. The transfered heat is calculated by numbers then, surface radiation values are added to calcualate the same conditions surface radiation heat with the help of resistance circuits, theoretically (Teke, 2003).

Yamankaradeniz and Kaynaklı, the energy losses from different parts of human body, produced sweating amount and found the wetness of the skin according to these factors. Considering the heating comfort differences, transfer of the heat and mass with environment of the human body that has been divided to 16 parts, has been simulated (Yamankaradeniz, 2003).

Experimentally, Olesen has conducted a comparative study on the performances of heating through panels on walls and floors. In this study, external temperature changes, solar beams entering through the windows, lighting and heat released by human being have all been considered as dynamic conditions. The results show that in both panel installments, thermal comfort can be reached. Additionally, the energy use of both systems are on the same level (Olesen, 1994).

Loveday and colleagueshas mentioned that in Fanger's study current design standard ISO 7730 's Fanger's key to the work, and particularly contained steady-state model of human heat equailty contained, equality,to give the set of thermal conditions, for human beings to feel the thermal comfort . They were monitored (Loveday, 2002).

Dağsöz, studied the subject of heating buildings with the use of solar energy. The study included heating with the use of solar collectors and heat pumps, heating with hot air, heating with the use of flooring and heating with the use of solar collectors (Dağsöz, 1998).

Chapter 2

THEORETICAL BACKGROUND

2.1Thermal Comfort

Almost all volumes used frequently by people are air-conditioned according to the summer/winter conditions via various systems. The main purpose of the usage of air conditioning systems is to provide the residents of the building with thermal comfort. Due to this reason, it is significant to understand and analyze the human body air-conditioning state and reactions in order to select an appropriate system and design.
Thermal comfort varying from person to person and the person is satisfied with the thermal environment is defined as a specified condition. The codition that is necessary for thermal comfort, there is a thermal balance between human body and environmentor unbalance is at acceptable level (Toksoy, 1994).

The heating of volumes which individuals are living in vent, or a suitable internal environment for individuals to obtain objective air conditioning. This climate can be defined as, the air quality and an appropriate thermal environment. Individuals are very different from each other.

It is not easy to keep all the people in an environment comfortable at the same time. For this reason, the International Standard ISO 7730 for thermal comfort, ASHRAE norms within 55-92 criteria, terms and conditions prescribed for a certain group of people. Characterized in grasping conditions, cold or heat from the body is often caused by discomfort (ASHRAE, 1992).

Even people may be different temperature places they can still have thermal comfort. It is a matter of thermal comfort with many physical parameters, only a sign that shall not be obtained with favorable air temperature (FANGER, 1970).

Comfort changes from person to person and under the same conditions people can show different reactions. However; since it is impossible to create nd enviroment that pleases everyone, desired conditions are determined by majority.In ISO 7730 standard optimum comfort conditions is eighty percent of people living in interior is satisfied in ASHRAE Standard 55-92 ninety percent is satisfied (ASHRAE, 1992).

Establishing a thermal balance between individuals and the heat of the environment is important because individuals can continue with their lives. In the case where the heat from the balance of individuals may not be in thermal comfort. Heat balance is the balancing each metabolic activities that produces heat and heat loss from the body. Thermal comfort is a state of being happy in the thermal environment that people are in.

The personal parameters that affect the thermal comfort are one's activity condition and clothing. The activity condition and clothing of an individual, depending on the conditions of the environment, causes sweating or shivering which forms a stability between the body and its' environment (Figure 1).

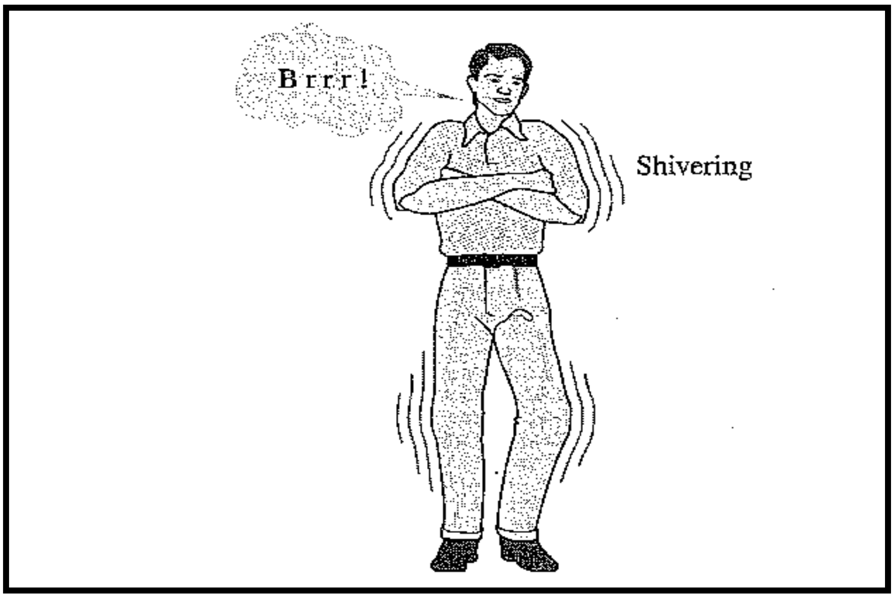

Figure 1: The Rate of Metabolic Genertion May Go Up Six Times The Resting Level During Total Body Shivering in Cold Weather (Çengel, 2003)

The human body, with its' food and oxygen intake, can be considered a low temperature, heat dissipating thermodynamic system which produces mechanic work. The metabolic energy produced by the body is diffused into the environment through convection and radiation with sensible thermal and and through the skin with latent heat and also by respiration through the lungs (Figure 2, 3).

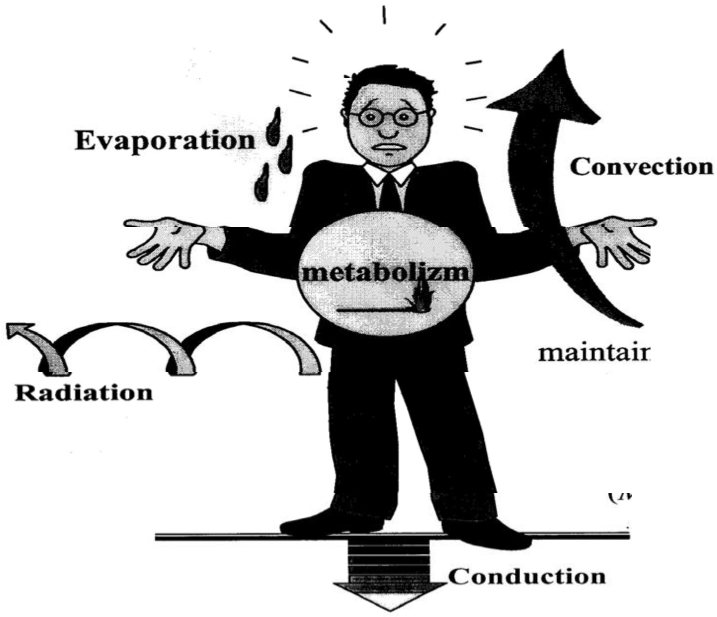

Figure 2: Thermal Balance of Human Body (Atikol, 2011)

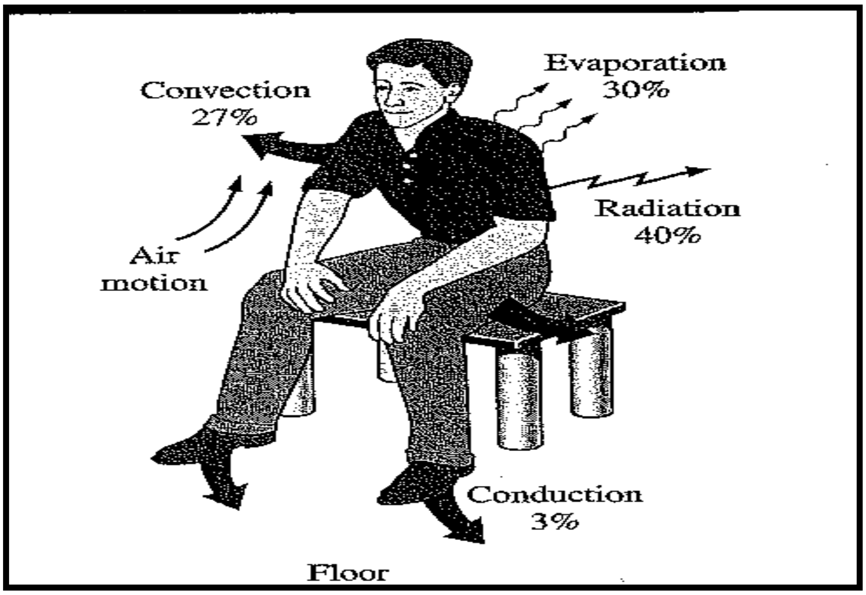

Figure 3: Machanisms of Heat Loss from the Human Body and Relative Magnifudes for a Resting Person (Çengel, 2003)

In order to feel total comfort within an environment, the body must produce an equal amount of energy which it is throwing out of the body into the environemnt. The body has complex physiological mechanisms that keep the body temperature at 36.8°C during various situations in order to protect the functions of the vital organs.

The easier a body forms an energy balance with the environment it is in, in other words the less physiological control mechanisms are needed, the body feels more comfort with the environment it is placed in.

The environmental parameters that affect thermal comfort are; the temperature of the environment, humidity, air movement and the radiation temperature of the surfaces around the person.

The human body has a structure which is affected by the climatic conditions around it, therefore it is an inevitable fact that the human body will react to the hot or cold environmental conditions.

The envorment temperature affects the perceptible and latent heat formed by the skin and respiration. While for a clothed person resting or doing light duties an operative temperature between 23°C - 27°C provides comfort conditions, for a person with no clothing the temperature for comfort is between 29 °C - 31 °C (Figure 4).

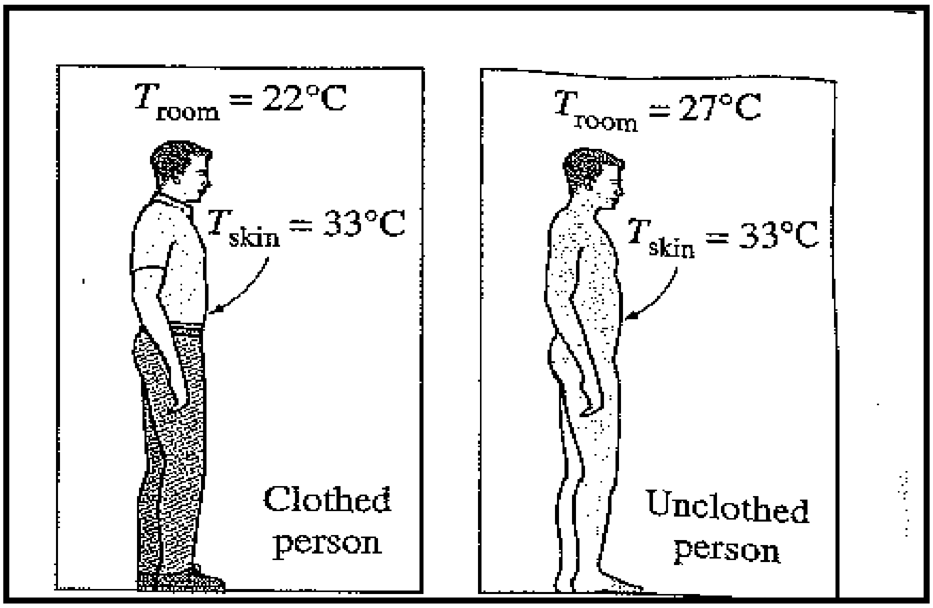

Figure 4: Cloting Serves as Insulation, and the Room Temperature needs to be Raised when a Person is Unclothed to Maintain the same Comfort Level (Çengel, 2003)

Due to the fact that relative humidity is a measure for the amount of humidity can be absorbed by the air and therefore affects the amount of heat evaporated from the body, it is a significant factor on the thermal comfort. The desired relative humidity rate is between 30% and 70% although the most acceptable relative humidity rate is 50%. Another factor that may affect the thermal comfort is air movements such movements high speed air movements may result in regional cooling which may lead to regional uncomfort. The desired air speed, accordingly with the summer or winter weather conditions, usually varies between 0.15 m/s and 0.25 m/s (Çengel, 1993).

Radiation temperature is another parameter which affects the operative temperature and as a result the perceptible heat which is released from the body. Due to the high temperature of radiation, controlling the air movements and keeping them at the desired values, will not be enough to provide the residents with thermal comfort.

Even if the temperature of the walls and surfaces are within the comfort rate, it may give a hot or cold sensation to the resident within the building. Therefore, if hot or cold surfaces exist within the environment, radiation temperature must be considered while calculating the comfort level (Figure 5).

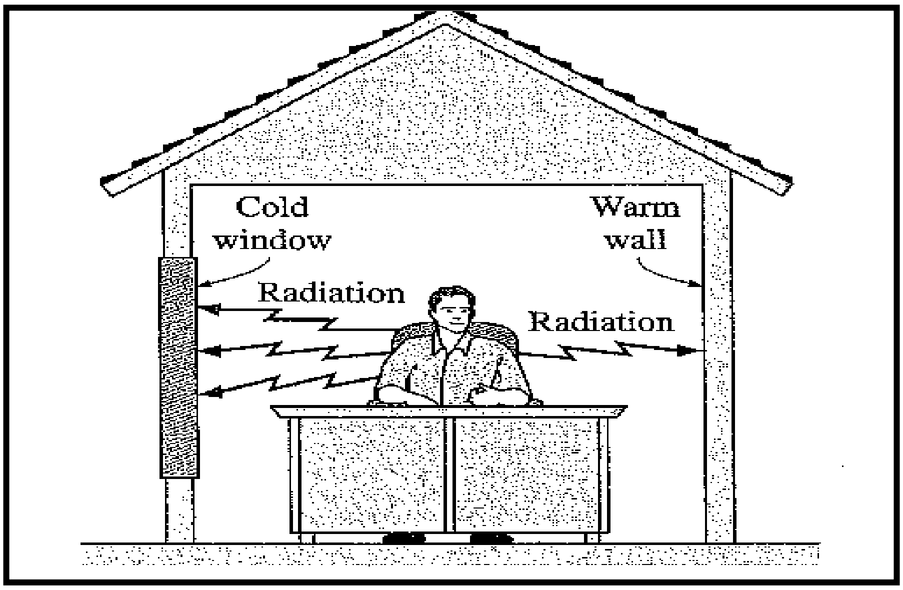

Figure 5: Cold Surfaces Cause Excessive Heat Loss from the Body by Radiation, and thus Discomfort on the Side of the Body (Çengel, 2003)

Thermal Comfort Standard

Acceptable thermal comfort range in the international standards is ASHRAE Standard 55 – 2004 (ASHRAE, 2004) and ISO 7730 (ISO 7730, 1994). ASHRAE Standard 55 – 2004's title is "Thermal Environmental Conditions for Human Occupancy". This standard clearly identifies the condition which important part of people finds it as acceptable in an environment as thermal comfort. Humidity, air speed, metabolic ration and clothes insulation identifies the parameters the comfort ranges for given value given value for parameters. This comfort ranges can be examined by acceptable environmental heating conditions. Operative temperature is temperature that represents both air temperature and average radiation heat (ASHRAE, 2004).

Table 1: ASHRAE Thermal Sensation Scale

3 Hot	2 Warm	1 Slightly Warm	0 Natural	-1 Slighty Cool	-2 Cool	-3 Cold

Another ISO 7730'un title is "Moderate thermal environments – Determination of the PMV and PMV indices and specification of the conditions for thermal comfort". There are two aims in ISO 7730 (ASHRAE, 1981).

• For people who are exposed to average thermal environment, present a method to estimate the degree of thermal feeling (PMV) and thermal discomfort (PPD) (Figure 6).

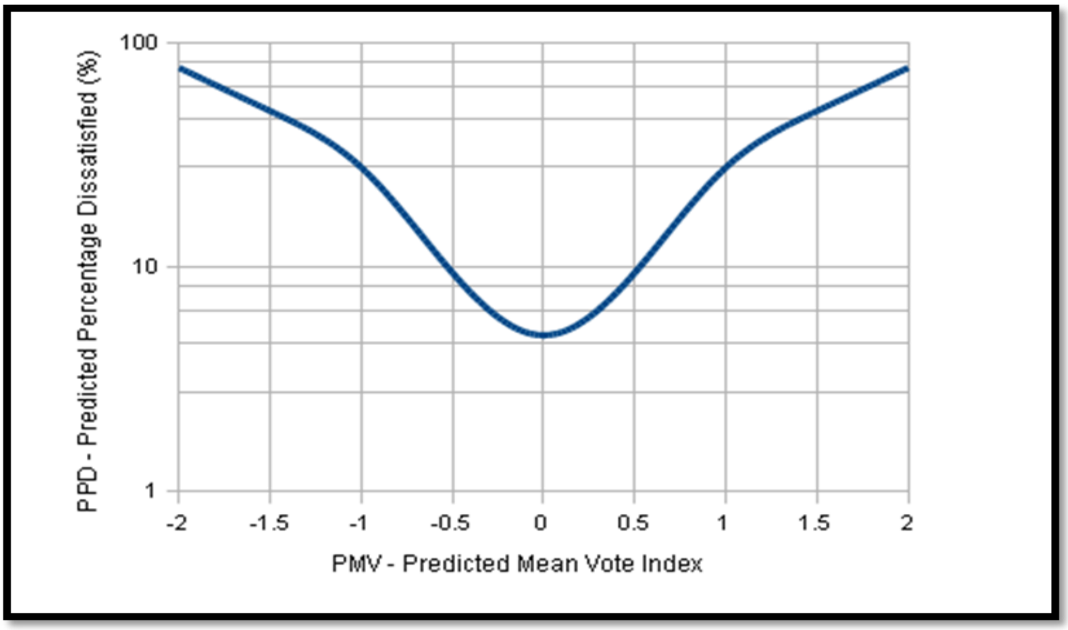

Figure 6: Relation between Predicted Percentage of Dissatisfied (PPD) and Predicted Mean Vote (PMV) (FANGER, 1970)

• To specify environmental conditions for acceptable thermal comfort. In ISO 7730 environment conditions for thermal comfort, are recommended separately as mostly in sitting activities for heating and cooling. In these recommendations for summer time clothing insulation 0.5 clo, for winter period clothing 1 clo were accepted.

Today advanced model of thermal comfort Fanger that is used, thermal comfort model takes into account the energy balance and ignores the steady temperature distribution in the body.

This model handles body as control volume that is restricted with only skin of the body temperature, to have steady-state thermal equilibrium with the body and environment and the skin temperature, the heat lost by sweating emphasized the necessity of the presence of certain limits. In Fanger model it was accepted that body temperature does not change over time, it is called continuous regime energy balance model.

2.2 Description of the Heating Systems

Heating systems are creating the demanded comfort conditions artificially independent from exterior weather conditions in one or more spaces.

Heating systems is a great significance in human's lives. Therefore, the heating systems should be designed in a way that they will provide the settings where people can live in comfort and at economical prices.

When choosing a heating system, the advantages and disadvantages should be considered and the most suitable one should be chosen in terms of thermal comfort transfer the heat they receive through the heating fluids to inner space of the volume via transmission, transportation or radiation and thus, heat-up the volume.

The systems evaluated in this study are as follows:

- Central Heating Radiator Systems
- Central Heating Heat Pump Systems
- Central Underfloor Heating Systems

2.2.1 Central Heating Radiator Systems

It the type of heating that occurs when the energy produced at a heating center (boiler room) is sent to the heater, located at the space that needs heating, through a fluid. The water that leaves the boiler from the boiler room at 90 ^{0}C, returns to the boiler at 70 °C after giving its energy to the space.

The transfer of the heat to the setting air is done through conduction and radiation in radiator heating systems. The air at the space gets into the radiator through the opening under the radiator; it warms up as it goes through the wings and rises up. Then, mixes with the cold air of the space after passing through the grids on top of the radiator and finally, leaves its heat to the space and returns to the radiator (Dağsöz, 1998).

Radiators are categorized as follows according to their material type and form:

- **Cast-iron Radiators**

Cast-iron radiators heat-up and cool-down late due to the features of the material.Their surface area is wide and air-contact space is considerable. It is durable due to the high thickness of the material (Figure 7).

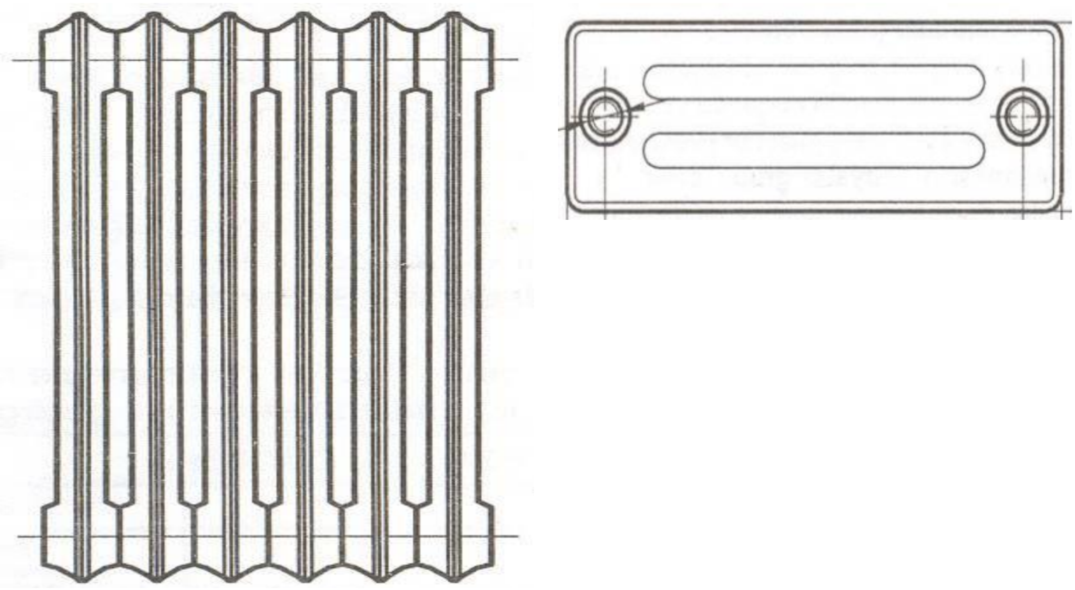

Figure 7: Sectional Cast-iron Radiator (Dağsöz, 1998)

- **Steel Radiators**

Sectional steel radiators heat-up and cool-down rapidly. They are cracking-resistant and they are non-durable (Figure 8).

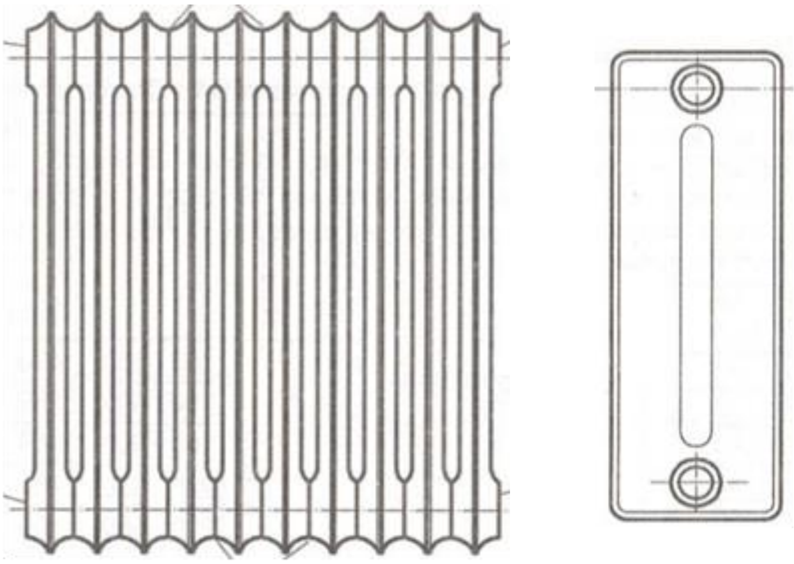

Figure 8: Steel Panel Radiator (Dağsöz, 1998)

- **Sectional Aluminum Radiators**

Sectional aluminium radiators are light-weight heaters due to the nature of the aluminium (Figure9).

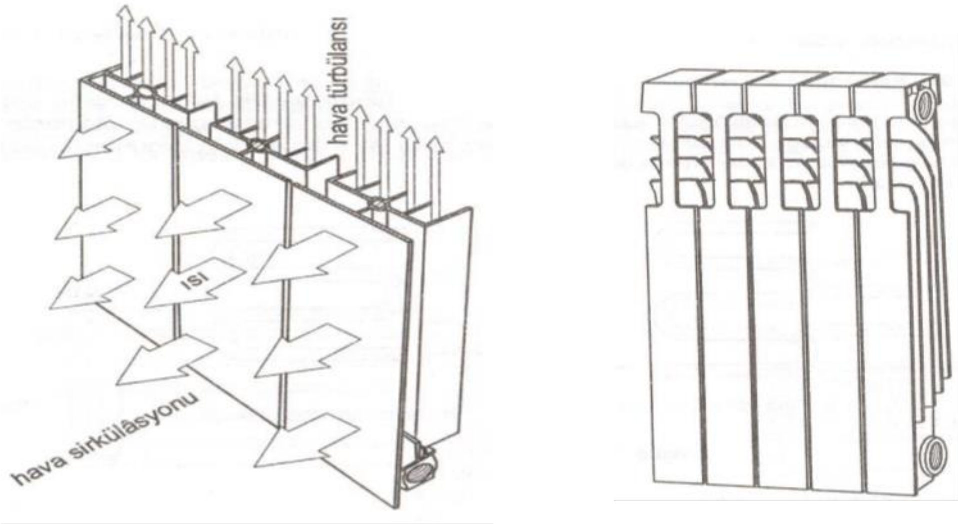

Figure 9: Sectional Aluminum Radiator (Dağsöz, 1998)

2.2.2 Central Underfloor Heating System

Underfloor heating systems are an heating system that distributes the energy from un heated water in the pipes under the concrete floor to floor of the building. The basic principle of the system is, in a place that temperature loss is calculated, the amount of energy that can be provided with circulation of hot water from special pipes under the covering of the floor. Warm water is spreaded out to whole covering area and homegenic heating is provided (Arıcı, 2010) (Figure 10).

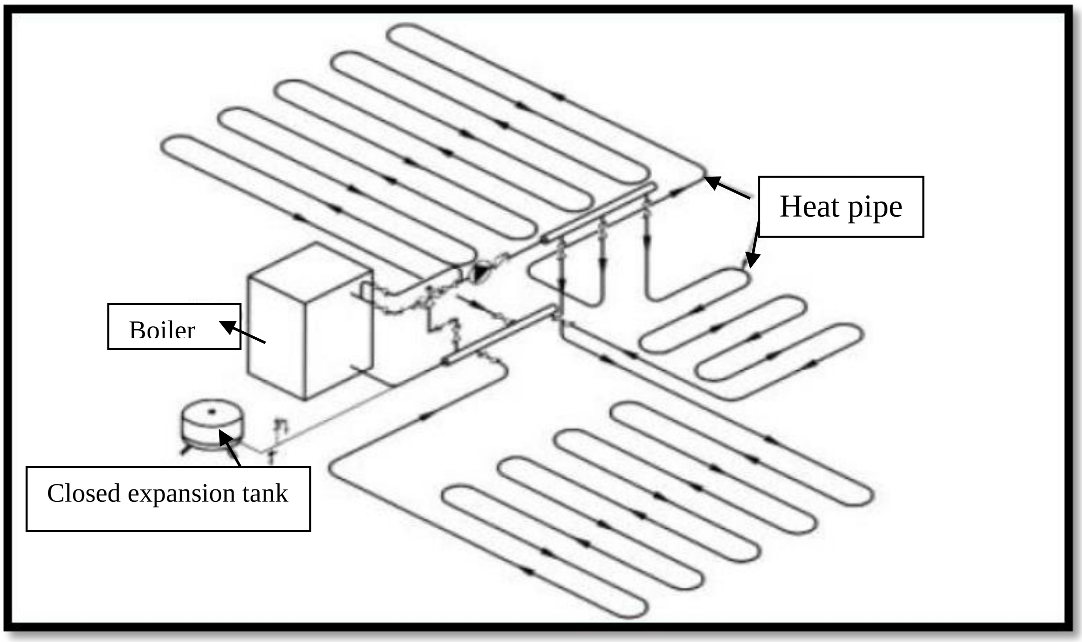

Figure 10: Underfloor Heatin System Application (Arıcı, 2010)

Underfloor heating systems are classification;

- Radiant Underfloor Heating Systems
- Watered Underfloor Heating Systems
- Infrared Underfloor Heating Systems

- **Radiant Underfloor Heating System**

Radiant underfloor heating systems are a heating system that distributes the energy from heated water in the pipes under the concrete floor of the building. In low temperature, heating water is obtained by central heating. Distribution is only made between colons and floors (Figure 11, 12).

Figure 11: Radiant Underfloor Heating System (http://www.ideal-heating.com/)

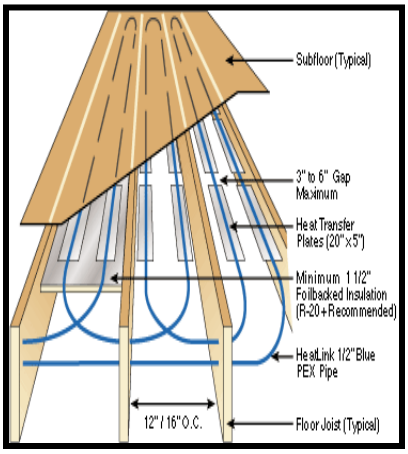

Figure 12: Detail of Radiant Underfloor Heating System (http://www.a2energy.com/ pages/radiant.php)

➢ Watered Underfloor Heating Systems

In Watered underfloor heating systems, water passes through pipes resistant to high temperature. These special pipes are placed under the covering. Pipes are connected to boiler room. Temperatures are set up as desired and make water circle through pipes. That how it get volume (Figure 13, 14).

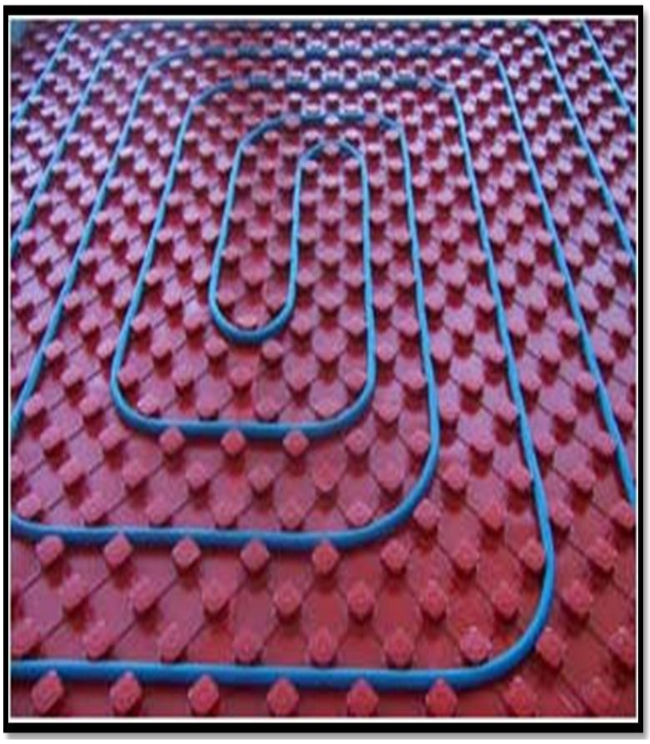

Figure 13: Watered Underfloor Heating System (http:www.dakservice.co.uk/underfloor- heating)

1. Concrete floor
2. Pipesulation Board 1m x 1m
3. Screed 50mm – 75mm
4. Floor covers
5. Border Insulation
6. Underfloor Heating Pipe

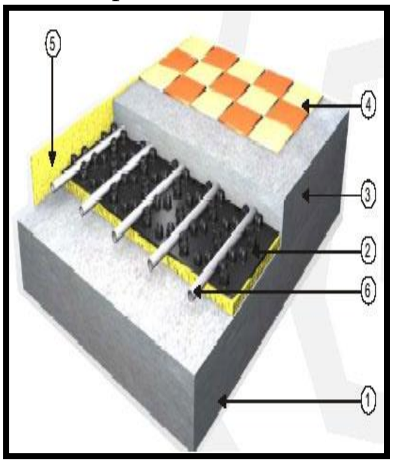

Figure 14: Detail of Watered Uderfloor Heating System (http://www.hpwarehouse.co .uk)

- **Infrared Underfloor Heating System**

Infrared systems on the floor, on some places it colder or hotter disappear. It is placed under a thing structure like carpet and it warms the whole volume in small time. (Figure 15, 16).

Figure 15: Infrared Underfloor Heating System http://www.ebay.com/itm/ nfrared-Warm-Floor-Heating-system-for- laminate-floorings)

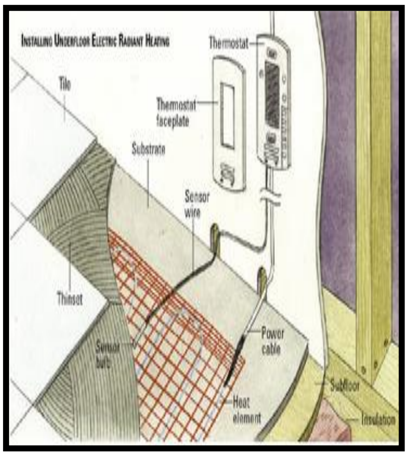

Figure 16: Detail of Infrared Uderfloor Heating System (http://www.blinkenergy.ca/infrared-heater- installation.html)

2.2.3 Central Heating Heat Pump Systems

Heat pumps are systems that transfer heat from one setting to another. The system takes its energy from electricity.

In the heat pump system; the cooling fluid enters the evaporator at evaporation temperature which is lower than the room temperature. A heat current occurs from the setting to the evaporator in order to provide the evaporation heat content of the cooling fluid. The evaporated fluid is then, compressed and its temperature rises during this process. The hot vapor enters to a heat exchanger located in the setting where the recycled heat will be given. This is where the heat fluency to the setting through the high temperature cooling fluid (Heap, 1983) (Figure 17).

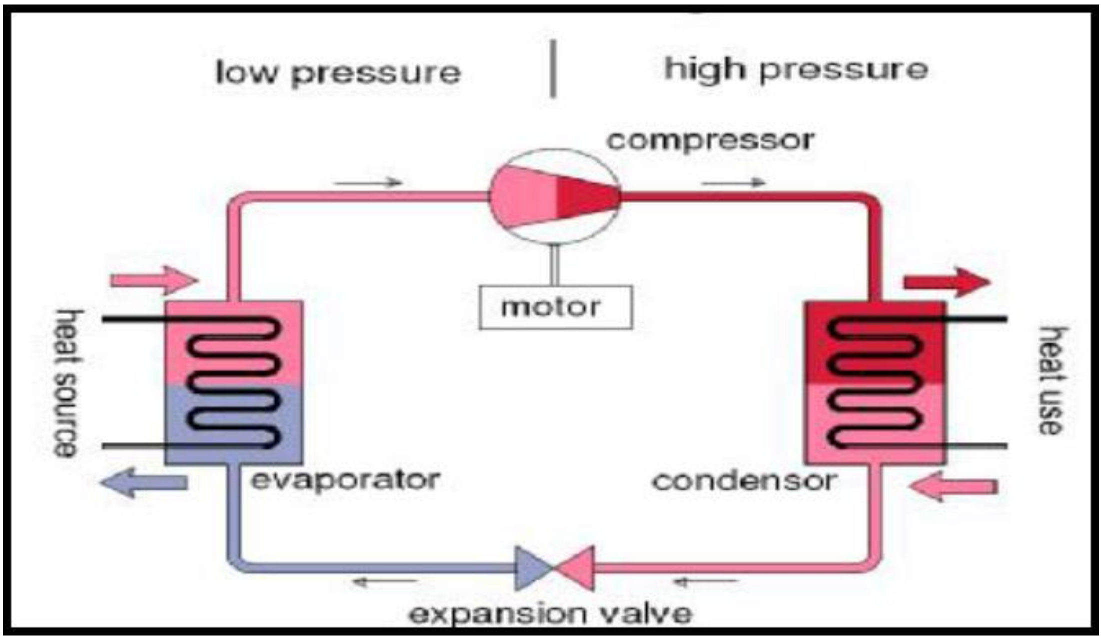

Figure 17: Schematic Diagram of a Compression Heat Pump (Heap,1983)

Heat pumps are systems that transfer the low temperature heat energy of air, soil, underground and above ground resources; Geothermal and solar energy or waste heat energy to a higher temperature setting with the help of secondary energy resources.

Heat pump systems are categorized as follows based on their heat source:

- Soil source heat pump
- Water source heat pump
- Air source heat pump

2.3 Relation between Heating Systems and Thermal Comfort

A variety of heaters are used with the aim of bringing the frequently used spaces to the demanded comfort standarts. The purpose of the systems used to heat up volumes is to provide the thermal comfort standards for the building residence. If the body is able to form energy balance easily with the environment, in other words the less the control mechanisms interfere, the more comfortable the person feels in that setting (Çengel, 2003).

The way we feel the heat indifferent locations is dependent on the room temperature and heat circulation. In radiator systems the heat is spread to the environment in two ways; radiation and convection. In radiator heating systems the hot air rises above the head level and accumulates in the ceiling area. The hot air condensed in this area leaves its hotness at that spot and moves down after cooling. As the cold air contacts the ground it creates a cool and uncomfortable feeling at the feet level (Figure 18).

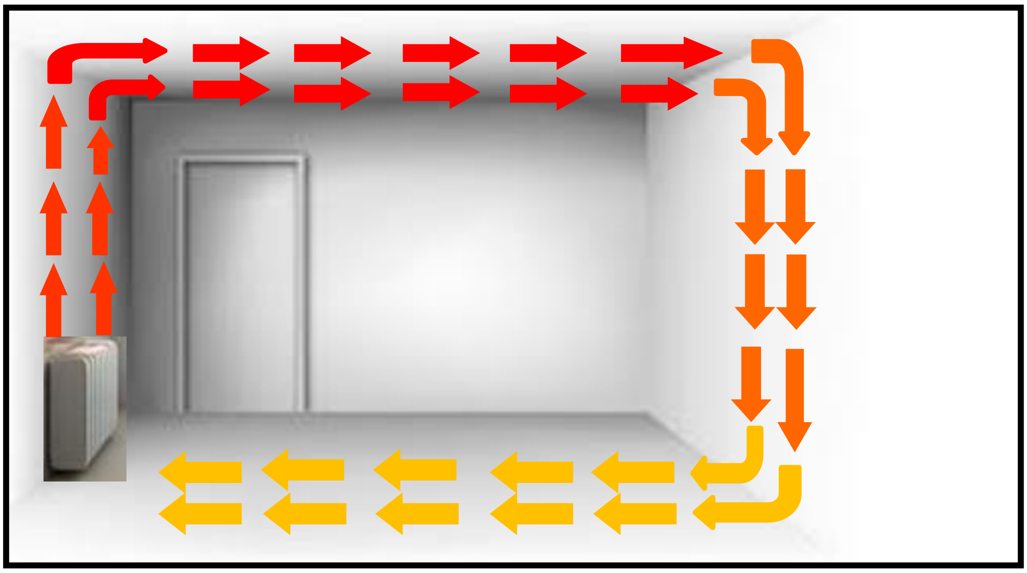

Figure 18: Diagram of a Radiator Heated Room with Heat Distribution

In a location with underfloor heating system, a more homogeneous heat distribution is enabled both horizontally and vertically. The heated air rises to the higher points of the space with a underfloor heating system. As the air rises to the higher points, the air movements weakens and air gets cooler. Thus, the warm air accumulated at the living volume of the space rather than higher points (Olesen, 2002) (Figure 19).

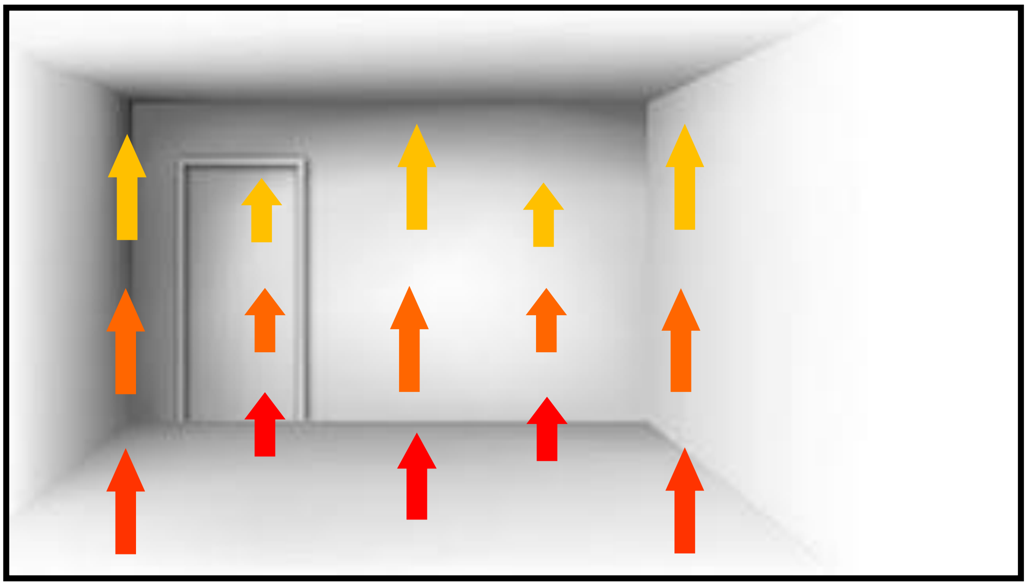

Figure 19: Diagram of a Underfloor Heated Room with Heat Distribution

Also, a more homogeneous heat distribution is obtained with this type of system. The heated air, that is close to the flooring surface rises and creates a natural circulation within the space. As a result of this, the hot air condenses in the space at about 1.5 m. above the ground. This uniform temperature distribution from the ground to the ceiling is the most suitable profile that observance the most ideal heat distribution profile in theory (Olesen, 2002).

2.4 Energy Efficiency of Heating System

Energy efficiency means using the energy more efficiently by developing the classical methods and using the new technology. The inclination toward highly productive and low-cost energy systems is raising due to the increased energy costs.

One of the important comparison aspects of heating systems is the coefficient of performance (COP). The coefficient of performance for heating systems is stated with COP values. COP is described as the ratio of energy produced per kW heating to the total consumed energy. When used for comparison purposes, the higher the COP the more productive the system is. The high levels of C.O.P values show the high quality and used of technology in that system.

The energy efficiency of the underfloor heating systems and radiator heating systems will be compared in terms of COP values for the purposes of this study. The comparison will be made based on the data collected from the Union of the Chambers of Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers.

2.4.1 Investment Cost

The top criteria for users when choosing a heating system for houses is the investment and operation cost. The scarcity of the resources usually pushes the user toward cheaper options. Investor, often, prefers systems with lowest cost and that can be completed at the shortest period of time possible. Actually, what is important is the total cost value of the system. In other words, the sum of operation and investment costs of the system during its financial life.

When compared with radiator heating systems, the underfloor heating systems are more expensive due to their material expenses. However, despite this more expensive investment cost, underfloor heating systems offer more affordable operation costs due to the constantly increasing energy costs of today’s world. As the temperature of the water fluent in the underfloor heating system is at lower levels than radiator systems, it enables energy efficiency and significantly reduces operation costs (Parmaksızoğlu, 2007).

In conclusion, underfloor heating systems provide a more efficient heating by consuming less energy cost. Additionally, as the underfloor heating systems offer energy efficiency through to low temperatures; it can also be easily combined with energy efficient systems by using renewable energy resources like soil heat and solar energy and this, in turn, considerably decreases the investment cost.

The underfloor heating and radiator heating systems that are included in this study will be compared from the investment cost aspect in the eveluation section. This comparison will be done based on the data collected from Union of the Chambers of Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers.

2.4.2Annual Energy Cost

Operation cost has become one of the most important factors while choosing heating system as the energy costs are continuously increasing. Operation costs are now rapidly going above the setup cost of the equipment. Thus, the most important issue when choosing heating systems is to find a system that can show high-performance with low fuel consumption.

In the present study; the annual cost of fuel cost are calculated with the aim of finding the system with the annual operation cost. The system that shows the highest performance with the lowest fuel expense is evaluated under the evaluation section.

2.5 Application Techniques of Heating System

It is crucial to apply the systems that will be used to warm the space in the correct way in order to form the needed thermal comfort and use energy efficiently.

The radiators to be applies in the building should be chosen based on their volume size, amount of heat loss and usage condition.

The radiators are placed on consoles that are buried in the masonry from below and are attached with clips from above.

In order for the environment air to enter the bottom of the radiator and move along the radiator before rising to the top, a minimum of 100mm. opening at the bottom, and a minimum of 40mm. opening at the back are vital (Dağsöz, 1998) (Figure 20).

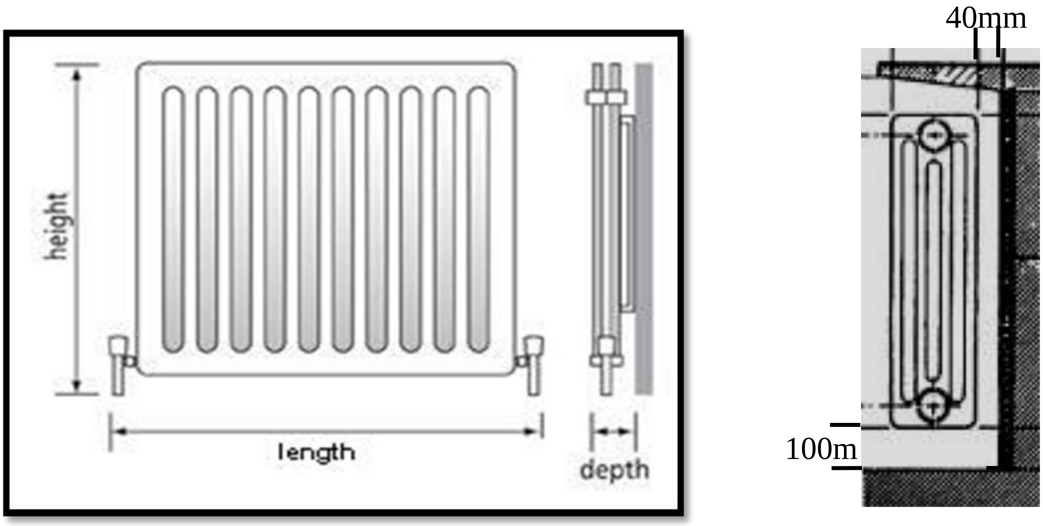

Figure 20: Radiator System Application (Dağsöz, 1998)

Radiator pipes can be applied in two ways: copper pipes or plastic pipes as infrastructure material (Figure 21, 22, 23). Water entrance is done from the top and it exits from the bottom. The installation pipes should be as short as possible and should be rotating at the minimum level while determining their direction. The connecting pipes should be given an inclination toward the heater on the go and an inclination toward the colon on the return at 1%. The connecting pipe length should not be less than 250mm and more than 150mm. Radiator valve should be assembled to the water entrance of the radiator, and a radiator rotating valve should be assembled to the exit (Karakoç, 1999).

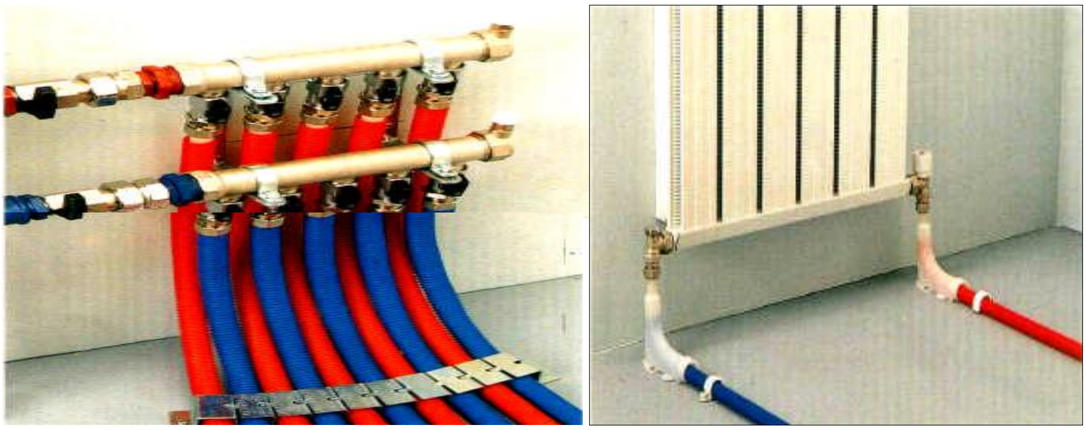

Figure 21 : Radiator Collector Details (Karakoç, 1999)

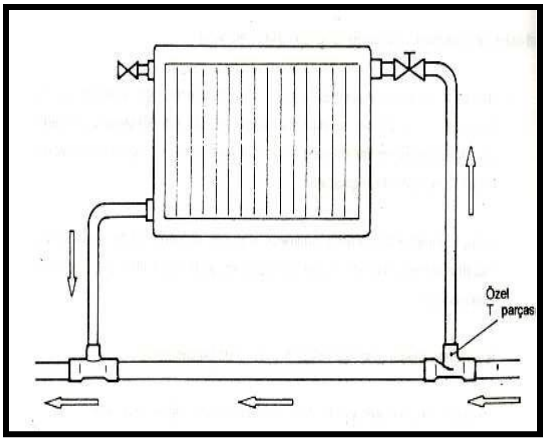

Figure 22: Cooper-Pipe Radiator Connection (ASHRE, 2003)

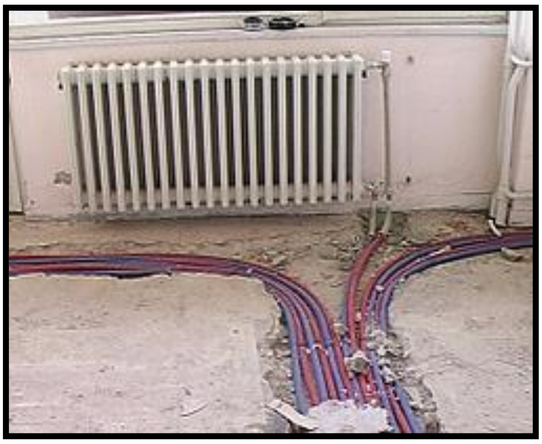

Figure 23: Plastic-Pipe Radiator Connection (Anonim, 2009)

As the underfloor heating systems are positioned in the mortar finish, the application should be done during the construction process of the building (Figure 24). The system is applied before the waste water and clean water plumbing is finished, interior rendering is done and flooring is completed. Styrofoam is laid as heat and sound insulator on the evened cement and the edges of the wall, followed by laying polypropylene foil. Later on, the sheet bars are fixated according to the flooring style and spacing between pipes. After pipes are set based on the flooring style and spacing between pipes, each opening is connected to the collector. The place of the collector should be applied in suitable distance to all space that will use floor heating pipes. A room thermostat should be used to maintain the 25-26^{0}C room temperatures (TMD, 2009).

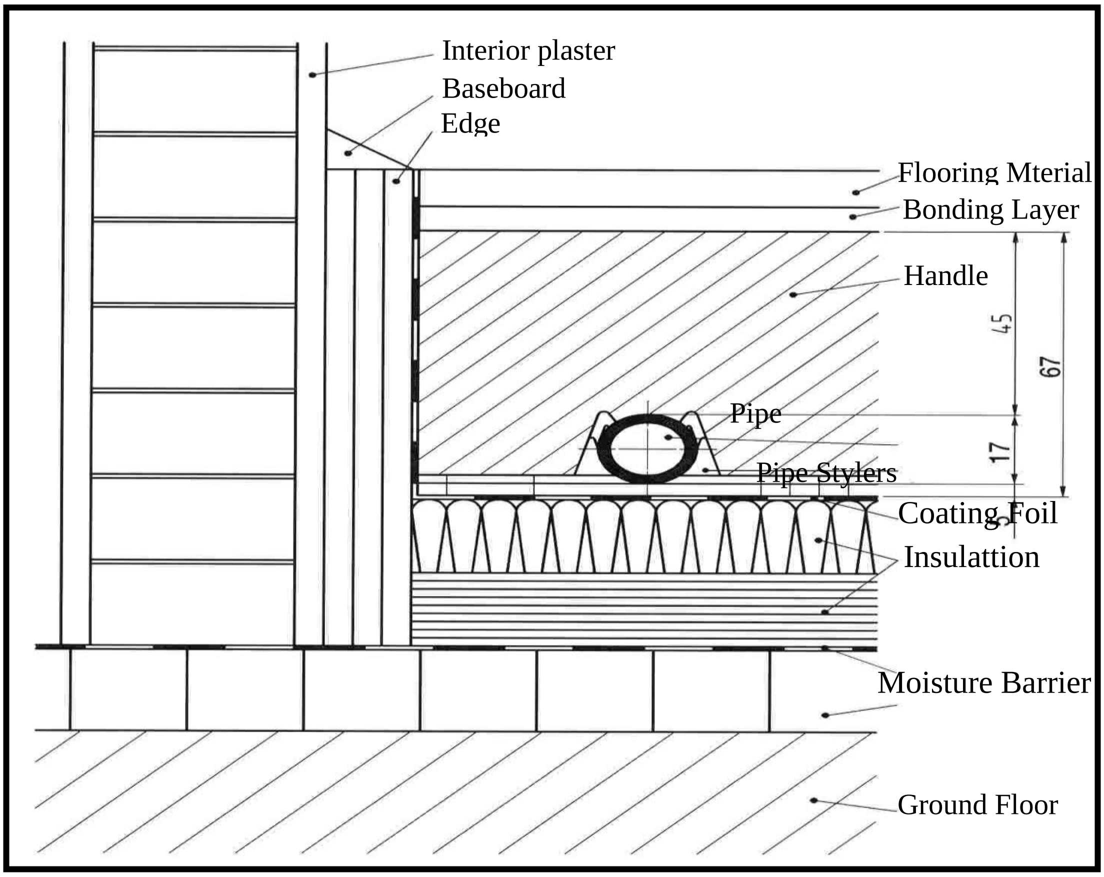

Figure 24: Underfloor Heating System Application Section (TMD, 2009)

2.5.1 Floorcovering

Which flooring material to use for which surface in floor heating systems is decided at the design process. After determining the flooring material, the thermal resistance is calculated based on the type of flooring. As each materials will have its unique heat transmission coefficient, the diameter of the pipes, flooring frequency and ground depth should be determined based on the materials chosen at the design process.

The flooring materials used in floor heating applications are:

- Laminate
- Carpet
- Stone and ceramic tiles, marble

➢ **Laminate**

It is suitable for all under floor heating systems with polypipe. Instead of the rigid panel type, the laminate flooring should be placed on a floor leveller of a roll-type. There should be an expansion gap around the neck of the floor to accommodate the occurring movement (Figure 25, 26)

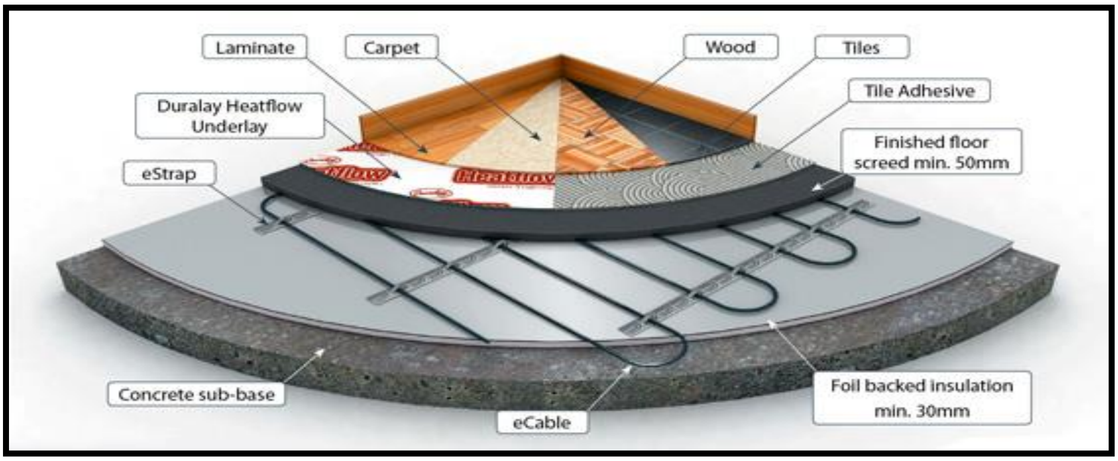

Figure 25: Laminate Flooring Details (http://www.heatandplumb.com/acatalog/eCable_Electric_Underfloor_Heating.html)

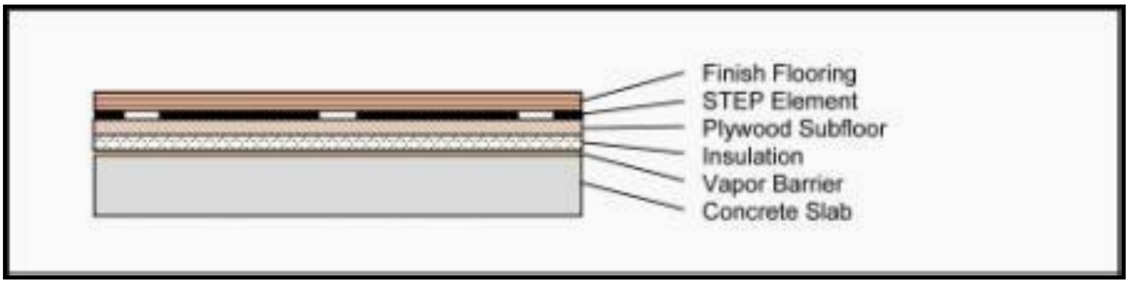

Figure 26: Installing Underfloor Heating Under Laminate (http://www.electricunderfloorheatingsystems.com/install-heated-floors/under-wood.html)

➢ **Carpet**

It is suitable for all under floor heating systems with Polypipe. The nature and thickness of the carpet are the vital factors in good heat transfer. Sponge with a waffle pattern is the most preferred type as it allows a good heat transfer. The two types of underlay that should not be preferred are felt and rubber crumb as they can significantly decrease the system efficacy by insulation the floor surface and inhibit the transfer of heat (Figure 27).

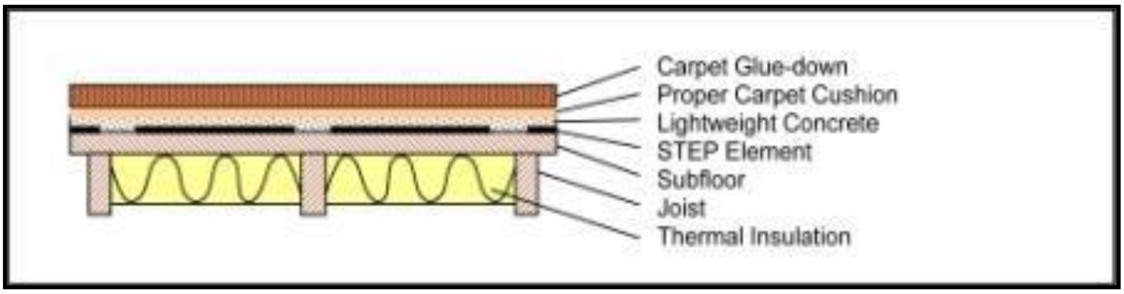

Figure 27: Installing Underfloor Heating Under Carpet (http://www.electricunderfloorheatingsystems.com/install-heated-floors/under-wood.html)

➢ **Stone and Ceramic Tiles, Marble**

It is suitable for all underfloor heating systems with Polypipe. Even though, they give a cold feeling on the ground, they can be turned into warm surfaces with comfort through underfloor heating systems. As these types are very brittle, it is crucial that the supporting floor is designed as stable and rigid, not to allow cracking. Use of flexible adhesives and grout is suggested for better results (Technical, 2009) (Figure 28, 29, 30).

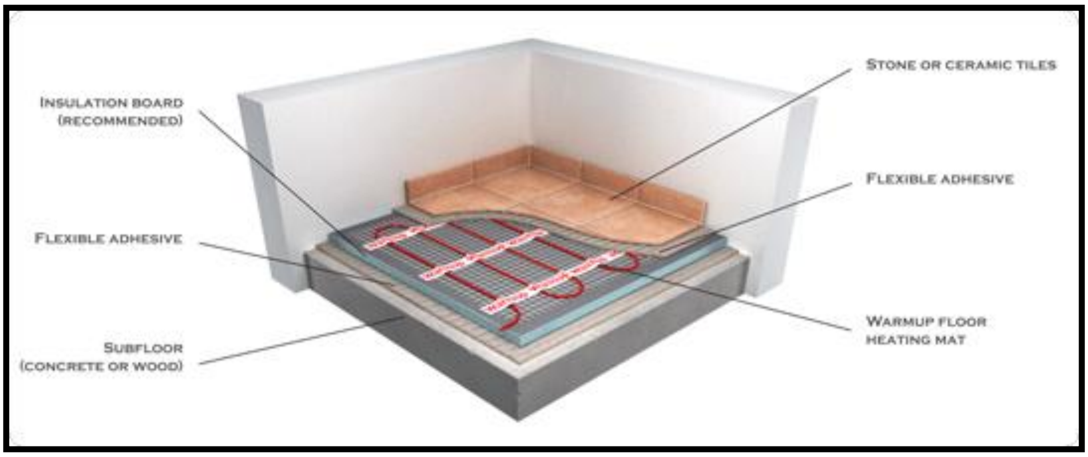

Figure 28: Stone, Ceramic or Marble Tiles Flooring Details (http://www.warmup.co.uk/uk/mat-underfloor-heating-flooring.phtml)

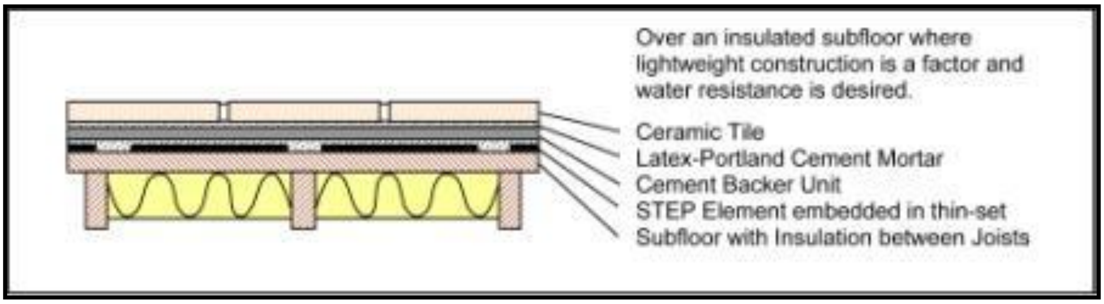

Figure 29: Installing Underfloor Heating Under Stone and Ceramic Tile (http://www.electricunderfloorheatingsystems.com/install-heated-floors/under-tile.html)

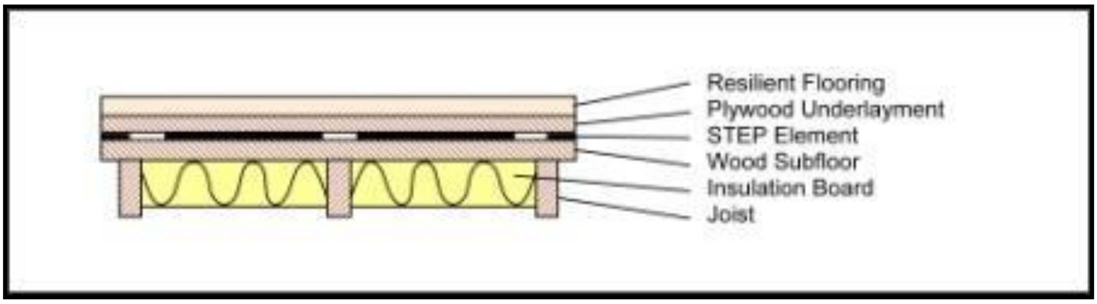

Figure 30: Installing Underfloor Heating Under Marble (http://www.electricunderfloorheatingsystems.com/about-us.html)

Flooring materials, heat transmission coefficient and thermal resistance are provided in the table below:

Table 2: Flooring Materials for Underfloor Heating and Their Features

Various Flooring Materials and Their Features Type of Material	**Thickness(mm)**	**Density (kg/m^3)**	**Heat Transmission Coefficient (W/mK)**	**Thermal Resistance (m^2K/W)**
Laminate	10	900	0,21	0,048
Carpet 335 g/m^2	6	-	-	0,07
Carpet 780 g/m^2	14	-	-	0,23
Ceramic Tile	10	-	1	0,01
Marble	30	2500	2,1	0,014

The table above shows the comparison between the various flooring materials, heat transmission coefficients and thermal resistance in underfloor heating systems. As a result of this comparison, it is seen that, because they transmit the heat well and keep the heat for the longest period, stone and ceramic are the best flooring materials. Marble floors require more energy to hold the heat and warm-up the house. The heat transmission coefficients are very low with wood and carpet surfaces. Besides, wood surfaces may lead to dryness of the flooring depending on the level of heat applied. Therefore, minimum level of heat should be used with wood surfaces.

2.5.2 Mainenance and Operation MCO cost (annual)

In order for the heating systems used for spaces produce an efficient and balanced heating, it is crucial to apply the systems in the correct way. The mistake in the instalment of high-cost and difficult-to-apply heating systems result in unbalances in the room temperature, not-sufficient heating or extreme heat. Additionally, as a result of the misapplication, potential environment-related problems may arise in relation to the low quality materials and low structure quality.

The rest of this section will discuss the issues needed to be considered while applying the heating systems used for heating spaces.

The most important issue while applying the heating systems is the quality and durability of the instalment pipes. In these systems, it is a must to use high-quality pipes and connectors which provide the heat transmission. Any malfunctions related to the pipes lead to expensive fixing costs that are difficult to change. Hence, the attention paid to the application of the system as well as the quality of the materials not only make the system more durable but also prevents future malfunctions.

With water system, the performance is high at the beginning because the pipes and radiators are clean. However, the residues accumulating in the pipes and radiators will make the diameters of the pipes smaller cause reduction in the water fluency amount and blockages in the radiators at certain levels due to usage over time. Also, the fuel quality pollutes the ignition system of the equipment and increases energy consumption. This leads to more energy costs or reduced heating performance.

For this reason, the attention paid to the application of the system as well as the quality of the materials not only make the system more durable but also prevents future malfunctions.

2.6 Renawable Energy use in Heating System

Another method of energy saving in buildings is to use the energy produced from renewable energy resources rather than limited resources.

Renewable energy resources are the sources that produce energy from the energy current occurring in the continuous natural processes. Generally, renewable energy resource is defined as renewing itself at a speed equal to the energy taken from the source or even more rapidly (Uyarel, 1987).

- **Space Heating with Solar Energy**

The hot water heated and stored with solar energy (collectors) is sent to the heating system pipes, thus heating the residences.

Even though, the operation costs of solar energy hot water heating system are almost non-existent, the major cost of such systems is the first investment cost. The first investment cost pays itself back at a short time and these systems are used to provide hot water for years with to cost. At places where solar energy is not sufficient, secondary heater starts functioning and handles the hot water heat load of the building (Utlu, 2004)

The design of radiator heating systems at an average of 70°C (90°C go, 70°C return) temperature and using heater with small surface areas makes it difficult to use active solar energy heating systems with fluid. Generally, the fluid temperature does not exceed 90°C at the exit of the collector in plane collectors. The temperature of the water stored in the storage unit is usually under 90°C. In that case, low-temperature fluid recycles in the heater equipment cycle used for heating the location (Figure 31). For this reason, as solar energy systems requires wider surface areas than radiator heating systems; they work more efficiently with underfloor heating systems(Uyarel, 1987)

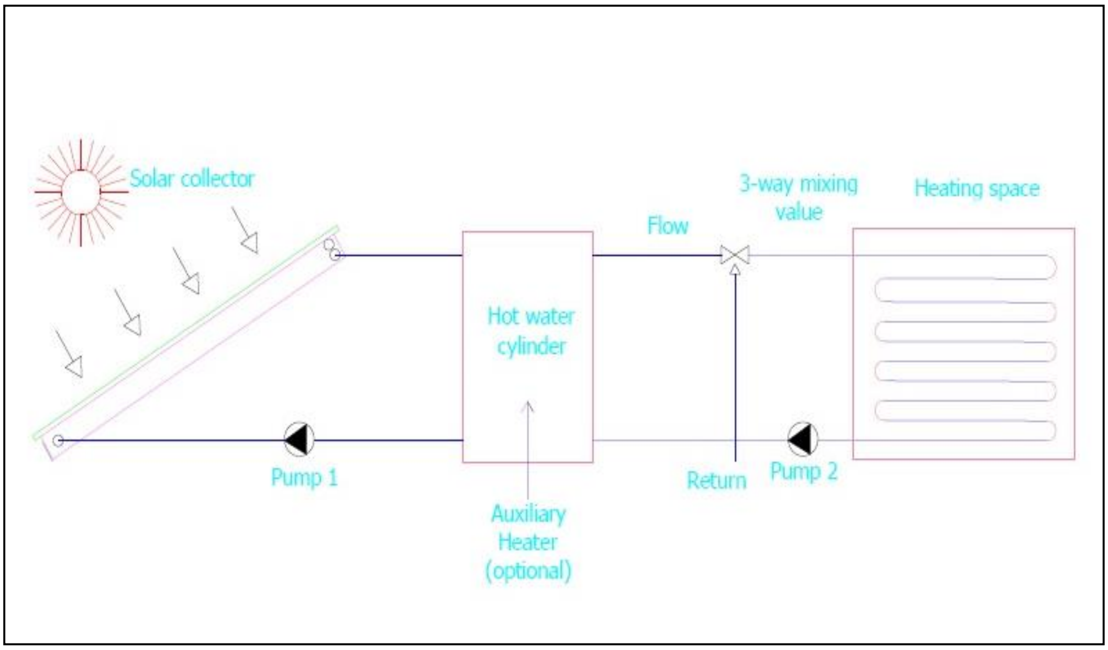

Figure 31: Space Heating with Solar Energy

The following table shows the evaluation of how to use underfloor heating and radiator heating systems with solar energy.

Tablo 3: Radiator Heating and Underfloor Heating Systems with Solar Energy

Types of Systems	**Required Water Temperature**	**Solar Energy Usage**
Underfloor Heating	40/35°C	Suitable
Radiator Heating	90/70 or 60/50°C	Not suitable

- **Space Heating with Geothermal Energy**

Geothermal energy is the heat energy inside the hot water, steam or gasses under the pressure accumulated in the different depths of the crust of the earth.

Geothermal heater fluid is brought to the surface with heat pumps. The heating fluid is carried to the spaces with the help of the pipes in the ground and residences are heated using this method. Geothermal fluid is between the temperatures 40-65°C. The heating fluid goes down at 35-55°C as a result of the heat losses in the pipes. The heating temperature is between 90-70°C in radiator systems so they are not suitable for geothermal energy. The temperature is between 25-29°C in underfloor heating systems and this makes them the most suitable system type for geothermal energy. (Demirel, 1999) (Figure 32).

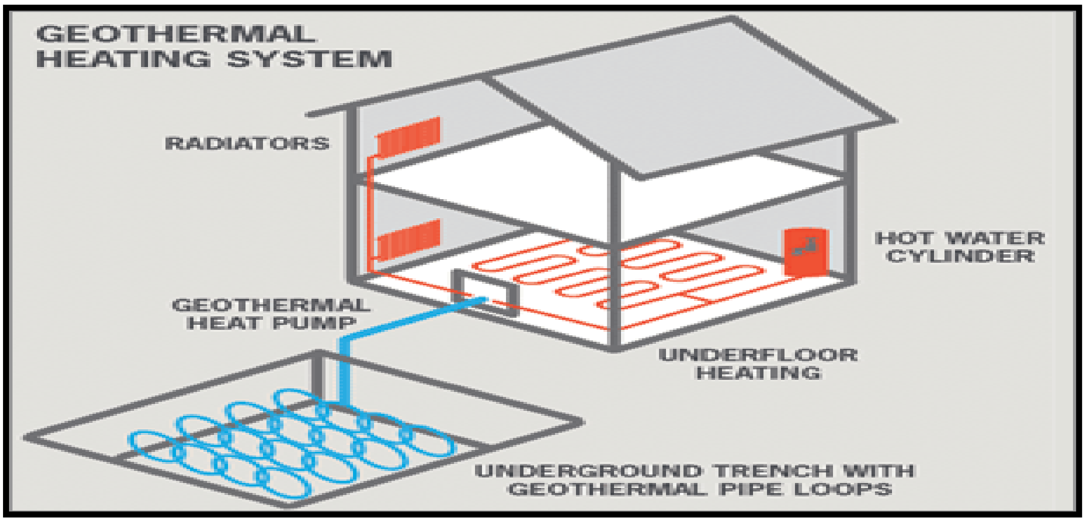

Figure 32 : Geothermal Heating System
(http://www.top-alternative-energy-sources.com/geothermal-heating-system.html)

- **Space Heating with Wind Energy**

Heating with wind energy is expensive and difficult. For this reason, heating with wind energy is not a preferred type of heating for spaces.

Chapter 3

EVALUATION OF THE HEATING SYSTEM IN TERMS OF THERMAL COMFORT, ENERGY EFFICENGY AND APPLICATION TECHNIQUES

3.1 Evaluation of the Heating System in Terms of Thermal Comfort

As the human body is affected generally by the temperature at 1,00-1,50 m. height, they mostly use radiation to meet their heating needs. The heated air, that is close to the underflooring surface rises and creates a natural circulation within the space. The hot air condenses ain the space at about 1.5 m. above the ground. This uniform temperature distribution from the ground to the ceiling is the most suitable profile that fits the most ideal heat distribution profile in theory (Olesen, 2002). On the other hand, the hot air condenses above head level in radiator heating systems and this does not fit to the ideal temperature profile (Figure 33).

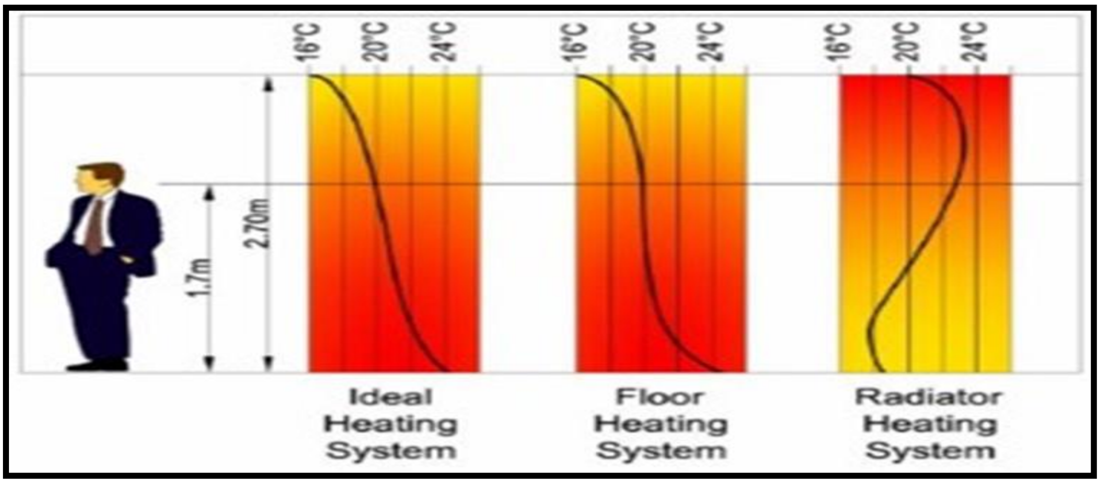

Figure 33: The Heat Distribution Profile. As the Above Drawing Shows, Underfloor Heating is the Ideal Floor Heating (ASHRA, 2003)

Rest of this section includes to comparison of the way heating systems heat residences are evaluated in order to find the system that is the closest to the ideal temperature profile.

The radiator systems have to heat all the air in the setting in order to heat the residence. The hot air heated in the heat supply, warms the air of the residence by creating convection current in the space. As the density of the hot air is reduced, it forms a hot air layer under the ceiling. The heated air cools down as it moves to the ground and finally reaches the area where people are living. As the air contacts the cold ground, it creates a cool and uncomfortable feeling at the feet level. This leads people feel uncomfortable at the areas they are at.

Additionally, these systems heat the air of the setting and thus, create a decrease in the relative humidity of the setting (Figure 34).

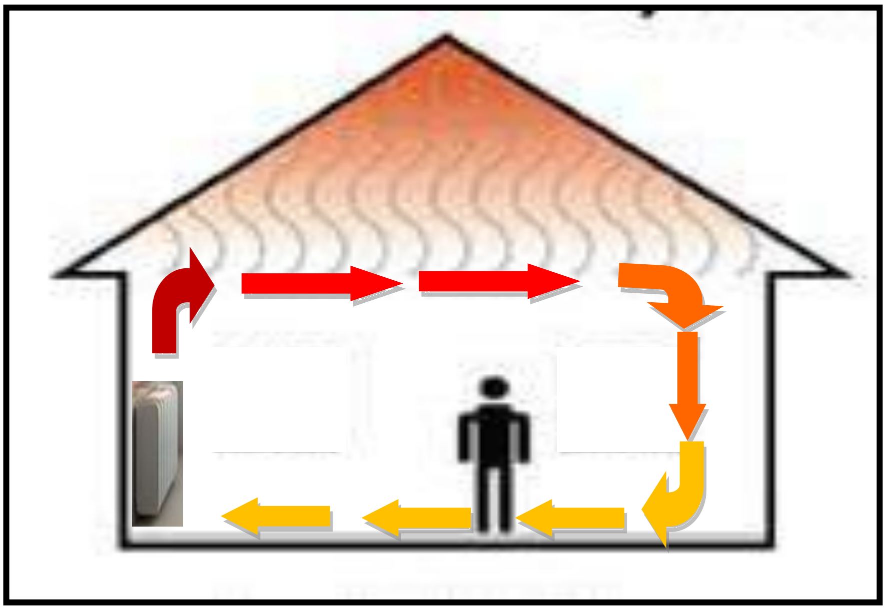

Figure 34: Diagram of a Radiator Heated Room with Heat Distribution

Underfloor heating system meet the heating needs of their space by heating up masses on the wide surface that radiates. The heated air rises to the higher points of the space with a underfloor heating system. As the air rises to the higher points, the air movements weakens and air gets cooler. Thus, the warm air accumulated at the living volume of the space rather than higher points (Figure 35). The heat loss taking place through the constant contact of the feet surface with the flowing through transmission is replaced with the heat spreading from the ground surfaces. The felt temperature coming to the ground surface is 25°C and this is the temperature of the bottom of the feet of a health human being. Due to this heat transfer mechanism, the floor heating systems are accepted as the only heating system that is the most suitable for the human thermal-physiological needs among all the heating systems used in today's world (Parmaksız, 2007).

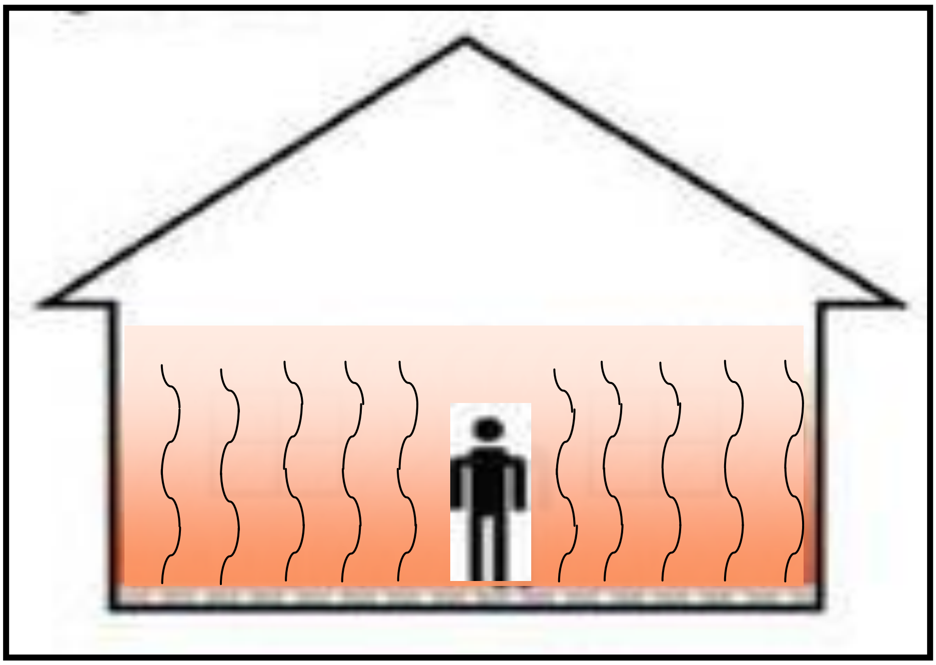

Figure 35: Diagram of a Underfloor Heated Room with Heat Distribution

Evaluation

In conclusion of the comparisons above; the law of physics proves that the uniform heat most suitable for human anatomy rises from the ground floor. When this heat transfer mechanism is considered, underfloor heating causes the least loss of heat between the human body and environment. (Olesen, 2002).

In radiator systems the heat rises above head level but after it comes down while cooling and when the air contacts the cold ground, it creates a cool and uncomfortable feeling at the feet level. In underfloor heating systems, as the hot air rises to the higher points, the air movements weakens and air gets cooler. Thus, the warm air accumulates at the living volume of the space rather than higher points. This creates a nice warm feeling at the feet and body of the people.

It was seen that radiator heating does not create a homogenous thermal comfort in the space; whereas, the underfloor heating which uses the whole floor as the heater is able to form a homogenous thermal comfort at different locations.

Additionally, the top temperatures in radiator heating systems are 28-30°C. In underfloor heating systems the bottom temperatures are 25-30°C and this is the bottom of the feet temperature of a healthy person (Anonim, 2009) (Figure 36).

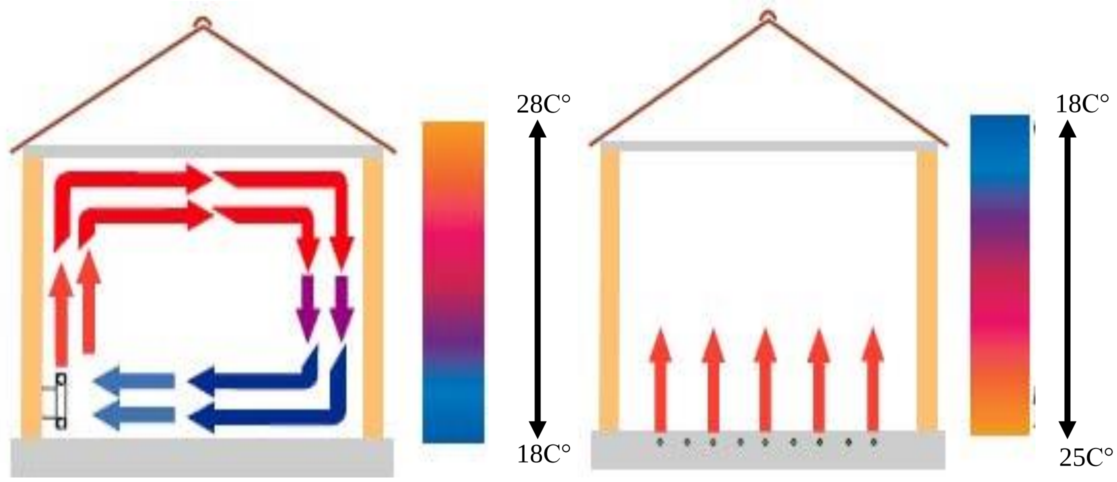

Figure 36: Radiator and Underfloor Heating Diagram (Anonim, 2009)

The dust floating in the air in our living space is the result of the air stream in the setting. The stream is caused by the exchange of places by the hot and cold air. The only way that makes it possible for the burning and floating of the dust particles which we cannot see is at high temperatures. This only happens because the water coming to our radiators in the high-temperature heater systems is at least 50°C, which burns the dust particles we cannot see and allow them to rise into the air. Dust burning only starts after 50°C. The operating temperature regime of the boiler water in underfloor heating systems is 45-50°C; the water running in the system is warm water at 30°C; and the temperature felt at the flooring surface is 25°C (Anonim, 2009). Underfloor heating systems do not work at high temperatures thus, there is no air current between hot and cold air. For this reason, it does not produce dust; and it is not possible for mites to grow in carpets or get moist.

3.2 Evaluation of the Heating System in Terms of Energy Efficency

3.2.1 Energy Efficiency Comparison of Radiator and Floor Heating Systems

100 m^2 residences with and without thermal insulation is taken as the basis for the comparison of radiator and underfloor heating systems in terms of energy efficiency. The data collected from Union of the Chambers of Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers was used in the comparison process. 40 kcal/h energy is required for a 1m^3 building with thermal insulation; and 55 kcal/h energy is required for a 1 m^3 building without thermal insulation.

When the systems used for residence heating reach the ideal room temperature, the thermostatic control valves step in. For this reason; the calculations for the systems discussed in this study were based on the assumption that the evaluated systems will work 120 days and 8 hours per year. The annual fuel amount was calculated on the conditions that use LPG, diesel oil, electricity and heat pump depending on the annual heat need. The results of the calculations are provided as tables and graphs.

- **Dimensions Calculation of 60°C - 85°C Panel Radiator System**

Below is the dimension calculation of a panel radiator system for a 100 m^2 residence. The height of the building is taken as 3m. And calculations are made for 60-85°C panel radiator systems.

- **Dimensions Calculation of 85°C Panel Radiator System**

The dimension calculation of a panel radiator system for a 100 m² residence. As the energy provided by a 1mt. radiator is 1800 kcal/h; a panel radiator with 6 mt. length and 60 cm. height should be used for hot water at 85°C (Figure 37).

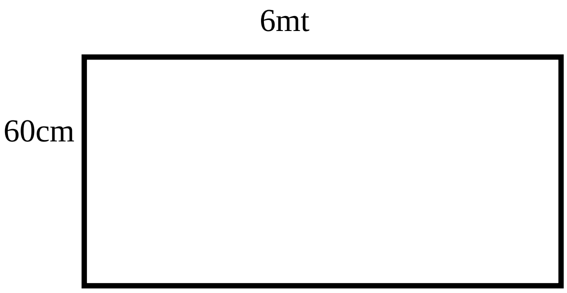

Figure 37: 85°C Dimension of Panel Radiator

As the energy provided by a 1m radiator is 1700 kcal/h a panel radiator of 8 m. length and 60 cm. in height is needed for 60°C of hot water (Figure 38).

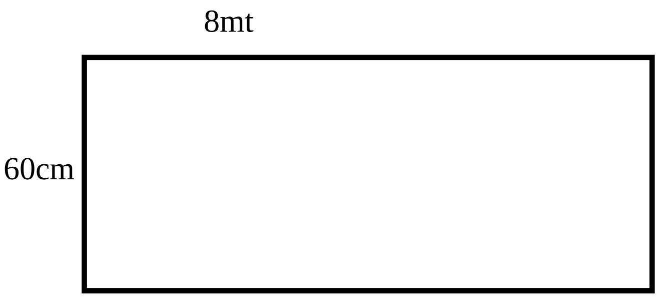

Figure 38: 60°C Dimension of Panel Radiator

1) **Investment Cost Calculation of Heating Systems**

The set up costs for radiator and underfloor heating systems for a 100 m² residence in TRNC conditions are handled in Table 4 and Table 5. The set-up costs in the tables have been calculated based on the data collected from Union of the Chambers of the Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers.

- **Investment Cost for Panel Radiator System**

Tablo 4:Investment Cost for Panel Radiator System (Union of the Chambers of Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers, 2013)

Investment Cost for Panel Radiator System	**The Unit Cost per m² in a 100m² Residence**
LPG 6500 € (Kombi+panel radiator+ sub-base pipes+gas tank+pipeline including)	65 €/m²
Diesel oil 7500 € (Kombi+panel radiator+sub-base+diesel tank+pipeline including)	75 €/m²
Electricty 3500 € (Electical panel radiator+including electric supply line)	35 €/m²
Heat Pump 8900 € (Heat pump+panel radiator+sub-base pipes+ including electricty supply line)	89 €/m²

- **Investment Cost for Underfloor Heating System**

Tablo 5: Investment Cost for Underfloor Heating System (KTMMOB Union of the Chambers of Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers, 2013)

Investment Cost for Underfloor Heating System	**The Unit Cost per m² in a 100m² Residence**
LPG 6500 x 1.3 = 8450 € (LPG+kombi+floor heating insulation foam and pipes+LPG tank and pipe line)	65 €/m²
Diesel oil 7500 x 1.3 = 9750 € (Kombi+kombi+ floor heating insulation foam and pipes+LPG tank and pipe line)	75 €/m²
Heat Pump 8900 x 1.3 = 11570 € (Heat pump+kombi+ floor heating insulation foam and pipes + İncluding electric supply line)	89 €/m²

2) Energy Cost of Heating Systems

The annual energy need is the need for energy during the constant regime in which the building exists through the heating season. The systems are assumed to be working for 120 days and 8 hours per year and the calculations were made based on that assumption for the purposes of this study.

The annual fuel consumption based on the annual heating energy need of the building is calculated in the (1) numbers equation (ASHREA, 2003)

$$\frac{\text{Fuel Cost} \times \text{Daily energy need of the Building}}{\text{Under Floor Heat Value of the fuel} \times \eta} \qquad [1]$$

The term η in the number (1) equation represents the efficiency of the fuel used.

The fuels used in this study are: LPG, diesel oil, electricity, heat pump. The data collected from Union of the Chambers of the Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers have been used to compare the systems. In radiator and floor heating systems 12000 kcal/h energy is required for a 100m² residence with thermal insulation; and 16500 kcal/h energy is needed for a 100m² residence without thermal insulation. COP values of the systems are given in Table 6 based on fuel types. For a good system the burning efficiencies of LPG and diesel oil fuels are: 0.85 for diesel oil, 0.9 for LPG, 1 for electricity and 3 for panel radiator heat pump, 4 for underfloor heating systems. However, is the system is not well-maintained these values go down and this increases the operation cost.

Average operation productivity COP Values, Lower Heating Values of fuel types, fuel unit cost for Radiator Systems are shown in Table 7; Average operation productivity COP Values, Lower Heating Values of fuel types, fuel unit cost for underfloor heating systems are shown in Table 8.

Table 6: COP Values for Hot Water Panel Radiator and Hot Water Underfloor Heating Systems

Fuel Type	**Hot Water Panel Radiator 85° C COP**	**Hot Water Panel Radiator 45°C COP**	**Hot Water Floor Heating 45 C° COP**
LPG	0.9	0.9	0.9
Diesel oil	0.85	0.85	0.85
Electricity	1	1	1
Heat pump	___	3	4

Table 7: Average Operation Productivity COP Values, Lower Heating Values of Fuel Types, Fuel Unit Cost for Radiator Systems

Fuel Lower Heating Values	**Flue Cost**	**Average Operation and Productivity Values COP**
LPG = 11000 kcal/kg	1 kg LPG = 4TL	0.9
Diesel oil = 10256 kcal/kg	1 kg Diesel 0il = 3 TL	0.89
Electricty = 860 kcal/kg	1kg Electricty = 0.5 TL	1 COP
Heat Pump = 860 kcal/kg	1 kg Heat Pump= 0.5 TL	3 COP

Table 8: Average Operation Productivity COP Values, Lower Heating Values of Fuel Types, Fuel Unit Cost for Underfloor Heating Systems

Fuel Lower Heating Values	**Flue Cost**	**Average Operation and Productivity Values COP**
LPG = 11000 kcal/kg	1 kg LPG = 4TL	0.9
Diesel oil = 10256 kcal/kg	1 kg Diesel 0il = 3 TL	0.89
Electricty = 860 kcal/kg	1kg Electricty = 0.5 TL	1 COP
Heat Pump = 860 kcal/kg	1 kg Heat Pump= 0.5 TL	3 COP

- **Radiator System Energy Cost Calculation for a 100 m² Residence with Thermal Insulation**

When a 100 m² residence with thermal insulation is assumed to be working for day 8 hours a day for a year, the required energy amount is 96000 kcal/day.

(Note: The heat need of a-100 m²-residence with thermal insulation (9600 kcal/day) is found by calculating the heat loss of the building).

The water temperature is 60°C in central heating systems that are used non-stop in residence heating. The system will work non-stop for 24 hours and the thermostatic control valves will be activated when the inner heat of the residence reaches the ideal room temperature as 22°C.

The daily fuel cost calculations for LPG, diesel oil, electricity and heat pump are given below based on the data collected from Union of the Chambers of the Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers.

$$\text{LPG} = \frac{4 \text{ TL x } 96000 \text{ kcal/day}}{11000 \text{ x } 0.9} = 38 \text{ TL/day}$$

$$\text{Diesel oil} = \frac{3 \text{ TL x } 96000 \text{ kcal/day}}{10256 \text{ x } 0.85} = 33 \text{ TL/day}$$

$$\text{Electricty} = \frac{0.5 \text{ TL x } 96000 \text{ kcal/day}}{860 \text{ x } 1} = 56 \text{ TL/day}$$

$$\text{Heat pump} = \frac{0.5 \text{ TL x } 96000 \text{ kcal/day}}{860 / 3} = 19 \text{ TL/day}$$

- **Radiator System Energy Cost Calculation for a 100 m² Residence without Thermal Insulation**

When a 100 m² residance with thermal insulation is assumed to be working 8 hours a day for a year, the required energy amount is 132000 kcal/day. In the light of these data, the calculations for daily fuel costs of LPG, diesel oil, electricity and heat pump are done bellow.

(Note: As the residence is without thermal insulation, the heat loss is more than the residences with thermal insulation. Thus, the daily need for heat is 132,000 kcal/day).

$$\text{LPG} = \frac{4\ \text{TL} \times 132000\ \text{kcal/day}}{11000 \times 0.9} = 53\ \text{TL/day}$$

$$\text{Diesel oil} = \frac{3\ \text{TL} \times 132000\ \text{kcal/day}}{10256 \times 0.85} = 45\ \text{TL/day}$$

$$\text{Electricty} = \frac{0.5\ \text{TL} \times 132000\ \text{kcal/day}}{860 \times 1} = 77\ \text{TL/day}$$

$$\text{Heat Pump} = \frac{0.5\ \text{TL} \times 132000\ \text{kcal/day}}{860 / 3} = 26\ \text{TL/day}$$

Table 9: Daily Energy Costs of a Panel Radiator 100 m² Residence Thermal Insulation

Flue Type	**Daily Energy Cost 100 m² Residence with Thermal Insulation**	**Daily Energy Cost 100 m² Residence with Thermal Uninsulation**
LPG	38	53
Diesel oil	33	45
Electricty	56	77
Heat Pump	19	26

- **Calculation of Underflooring Volume in Underfloor Heating System**

The calculation of flooring volume in underfloor heating system was done based on a-100 m²-residence. Approximately, 600m. heating pipes are needed to heat a 100 m² residence. The energy given in each meter is 13,6 kcal/h.

Calculation of flooring volume in underfloor heating system is calculated in the (2) numbers equation (Kreide, 1994)

$$Q = m'.\ C.\ \Delta T \qquad [2]$$

$$9000 = m'.\ 1.\ 10$$

$$m' = \frac{9000}{10} = 900 \text{ liter/h}$$

As underfloor heating system transfers the heat through conduction, the sending of low-temperature water (45-35^{0}C) is satisfactory. It is assumed that the ideal room temperature of a residence with thermal insulation would be "22^{0}C''. When the underfloor heating is initiated for the first time, the system keeps working non-stop approximately between 24-32 hours until it gets on a cycle. After the system gets on a cycle, the thermostatic control valves start functioning and the system works for only 6 hours. Therefore, the system consumes about 96000 kcal/day of energy when it is started for the first time. After getting on a cycle, this energy consumption reduces to 72000 kcal/day.

Below are the calculations made for the daily fuel consumption of underfloor heating system after it gets on a cycle.

- **Underfloor Heating System Energy Cost Calculation for a 100 m² Residence Thermal Insulation**

When 100 m² residence with thermal insulation is assumed to be working for 8 hours a day for a year, the required energy amount is 75000 kal/day.

The daily fuel cost calculations for LPG, diesel oil, electricity and heat pump are given below based on the data collected from Union of the Chambers of the Cyprus Turkish Engineers and Architects, Chamber of Mechanical Engineers.

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$$LPG = \frac{4\ TL \times 72000\ kcal/day}{11000 \times 0.9} = 29\ TL/day$$

$$Diesel\ oil = \frac{3\ TL \times 72000\ kcal/day}{10256 \times 0.85} = 25\ TL/day$$

$$Heat\ Pump = \frac{0.5\ TL \times 72000\ kcal/day}{860/4} = 10\ TL/day$$

- **Underfloor Heating System Energy Cost Calculation for a 100 m² Residence Thermal Insulation**

When a 100 m² residance without thermal insulation is assumed to be working for 8 hours a day for a year, the required energy amount is 99000 kcal/day. In the light of these data, the calculations for daily fuel costs of LPG, diesel oil, electricity and heat pump are done bellow.

$$\text{LPG} = \frac{4\ \text{TL} \times 99000\ \text{kcal/day}}{11000 \times 0.9} = 40\ \text{TL/day}$$

$$\text{Diesel oil} = \frac{3\ \text{TL} \times 99000\ \text{kcal/day}}{10256 \times 0.85} = 34\ \text{TL/day}$$

$$\text{Heat pump} = \frac{0.5\ \text{TL} \times 99000\ \text{kcal/day}}{860/4} = 14\ \text{TL/day}$$

Tablo 10: Daily Energy Cost Underfloor Heating System 100 m² Residance with Thermal Insulation

Flue Type	**Daily Enegy Cost of a 100 m² Residence with Thermal Insulation**	**Daily Enegy Cost of a 100 m² Residence without Thermal Insulation**
LPG	29	40
Diesel oil	25	34
Heat pump	10	14

3) Annual Operation Cost of Heating Systems

The costs of panel radiator with-without thermal insulation and underfloor heating with-without thermal insulation are given below based on the fuel type.

- **In Panel Radiator System, the Annual (120 days) Operation Cost of a 100 m² Residence with Thermal Insulation**

Table 11: The Annual Operation Cost of Panel Radiator System

Flue Type	**Unit Cost x Day**	**The Annual Operation Cost of a 100m² Residence with Thermal Insulation**
LPG	38 x 120	4560 TL
Diesel oil	33 x 120	3960 TL
Electricty	56 x 120	6720 TL
Heat Pump	19 x 120	2280 TL

- **In Panel Radiator System, the Annual (120 days) Operation Cost of a 100 m² Residence without Thermal Insulation**

Tablo 12: The Annual Operation Cost of Panel Radiator System

Flue Type	**Unit Cost x Day**	**The Annual Operation Cost of a 100m² Residence without Thermal Insulation**
LPG	53 x 120	6360 TL
Diesel oil	45 x 120	5400 TL
Electricty	77 x 120	9240 TL
Heat Pump	26 x 120	3120 TL

- **In Underfloor Heating System, the Annual (120 days) Operation Cost of a 100 m² Residence with Thermal**

Tablo 13: The Annual Operation cost of Underfloor Heating System

Fuel Type	**Unit Cost x Day**	**The Annual Operation Cost of a 100m² Residence with Thermal Insulation**
LPG	29 x 120	3480 TL
Diesel oil	25 x 120	2880 TL
Heat pump	10 x 120	1200

- **In Underfloor Heating System, the Annual (120 days) Operation Cost of a 100 m² Residence without Thermal Insulation**

Tablo 14: The Annual Operation cost of Underfloor Heating System

Flue Type	**Unit x Cost**	**The Annual Operation Cost of a 100m² Residence without Thermal Insulation**
LPG	40 x 120	4800 TL
Diesel oil	34 x 120	4080 TL
Heat pump	14 x 120	1680 TL

4) Calculation of Annual Energy Efficiency of Heating Systems

Taking the data gathered at the end of the calculations, the energy efficiency of heating systems in 100m² residence with and without thermal insulation is calculated. The annual energy efficiency of a 100m² residence is calculated with the (3) numbered equation (ASHREA, 2003)

$$\frac{\text{Underfloor Heating System Energy Cost - Panel Radiator Energy Cost}}{\text{Underfloor Heating System Energy Cost}} = \text{Fuel Efficiency [3]}$$

- **Energy Efficiency calculation for a 100m² residence with thermal insulation**

$$\text{LPG} = \frac{29 - 38}{29} = \%\ 31$$

It can be seen from the calculations made that underfloor heating systems are 31% more efficient than radiator heating systems.

$$\text{Diesel oil} = \frac{25 - 33}{25} = \%\ 32$$

It can be seen from the calculations made that underfloor heating systems are 32% more efficient than radiator heating systems.

$$\text{Heat Pump} = \frac{10 - 19}{10} = \%\ 90$$

It can be seen from the calculations made that underfloor heating systems are 90% more efficient than radiator heating systems.

- **Energy Efficiency calculation for a 100m² residence without thermal insulation**

$$\text{LPG} = \frac{40 - 53}{40} = \%\ 32.5$$

It can be seen from the calculations made that underfloor heating systems are 32.5% more efficient than radiator heating systems.

$$\text{Diesel oil} = \frac{34 - 45}{34} = \%\ 32.2$$

It can be seen from the calculations made that underfloor heating systems are 32.2% more efficient than radiator heating systems.

$$\text{Heat Pump} = \frac{14 - 26}{14} = \%\ 85.7$$

It can be seen from the calculations made that underfloor heating systems are 85.7% more efficient than radiator heating systems.

The energy efficiency of heating systems in 100m² residence with and without thermal insulation is calculated in the study. As a result of these calculations, it was concluded that a heat pump uses energy 90% more efficiently than other fuel types in a residence with thermal insulation. Energy efficiency is ensured when the systems work with heat pumps

Table 15: The Energy Efficiency Rate of 100 m² Residence With and Without Thermal Insulation

Flue Type	**The rate of energy fficiency for a 100m² residence with thermal insulation**	**The rate of energy efficiency for a 100m² Residence without thermal insulation**
LPG	% 31	% 32.5
Diesel oil	% 32	% 32.2
Heat Pump	% 90	% 85.7

5) Payback Period

In order to compare the radiator and underfloor heating systems in terms of payback period, the ratio of difference of savings amount gained from systems to the investment difference is calculated.

In the light of the data;

- **Payback Period of LPG System:**

The annual operation cost of LPG panel radiator:38TL/day ………....= 4560TL/ year

The annual operation cost of underfloor heating system: 29TL/day....= 3480TL/year

The amount of financial saving to be gained: 4560 -3480…………...= 1080TL/year

Set-up cost of panel radiator ……………………………………........= 6500€

Set-up cost for underfloor heating syste..……………........................= 8450€

Investment difference ……………………………………….............= 1950€

System’s period of redemption 1950 / 1080..…………………………= 1.8 year

- **Payback Period of Diesel Oil System**

The annual operation cost of diesel oil panel radiator: 33TL/day……= 3960TL/year

The annual operation cost of underfloor heating system 25TL/day…= 2880TL/year

The amount of financial saving to be gained 3960 -2880…………...= 1080TL/year

Set-up cost of panel radiator …………………………………..……...= 7500€

Set-up cost for underfloor heating system …………………………...= 9750€

Investment difference ……………………………………..……….....= 2250€

System's period of redemption 1080/2250…………………………..= 2 year

- **Payback Period of Heat Pump System**

The annual operation cost of heat pump panel radiator 19TL/day…….= 2280TL/year

The annual operation cost of underfloor heating system 10TL/day…= 1200TL/year

The amount of financial saving to be gained 2280 -1200…………...= 1080TL/year

Set-up cost of panel radiator ………………………………..........= 8900€

Set-up cost for underfloor heating system …………………….. …..= 11570€

Investment difference ………………………………………….…...= 2670€

System's period of redemption 1080/2670 …………………………= 2.4 year

As a result of the assessment made, the payback periods are; 1.8 years for LPG; 2 years in diesel oil system; 2,4 years in heat pump system. As it can be seen from the results, underfloor heating system with LPG is the most suitable systems in terms of payback period compared to the other systems. Considering that the durability of the systems are between 10-20 years, it was concluded that the systems will payback their investment cost in 1.5 or 2 years.

Evaluation

The residences in TRNC are heated by using different heat sources. This study determined the set-up costs and the amounts of LPG, diesel oil, electricity and heat pump to meet the heating needs. The annual fuel costs were calculated by using the fuel amounts based on fuel types. Whether the systems to be assembled would pay off within their durability period was decided as a result of the calculations.

According to Table 4, the set-up cost for panel radiator is more than underfloor heating system. However, when the payback periods are considered, it was concluded that it would be more suitable to use underfloor heating system with heat pump in residence heating. According to Table 11, the annual operation costs in radiator systems with thermal insulation are calculated as: 4560 TL with the highest LPG usage; and the lowest fuel consumption on the condition to use a heat pump as 2280 TL. The annual operation costs in underfloor heating systems with thermal insulation are calculated as: 3480 TL with the highest LPG usage; and the lowest fuel consumption on the condition to use a heat pump as 1200 TL (Chart 1, 2, 3). After considering the efficiency of the burning systems, the most suitable system for annual residence heating is accepted as the underfloor heating with heat pump.

The comparison of underfloor heating system and radiator heating system in terms of energy efficiency is provided above. The demanded comfort conditions are provided at a short time by using radiator heating systems. However, the system works at high rates while providing these comfort conditions; and this causes the system to consume more energy. In contrast, underfloor heating systems work at lower liquid rates. The water flowing in the system runs under the floor of the space at lower rates; the comfort conditions are provided at a longer period of time and at a slower speed. Energy efficiency is enabled due to the lower rates of the liquid temperature running in the system.

As a result of the comparisons made, it can clearly be observed that the lower rate temperature of the heating liquid in the underfloor heating system leads to reduction in operation and management costs as well as enabling energy efficiency.

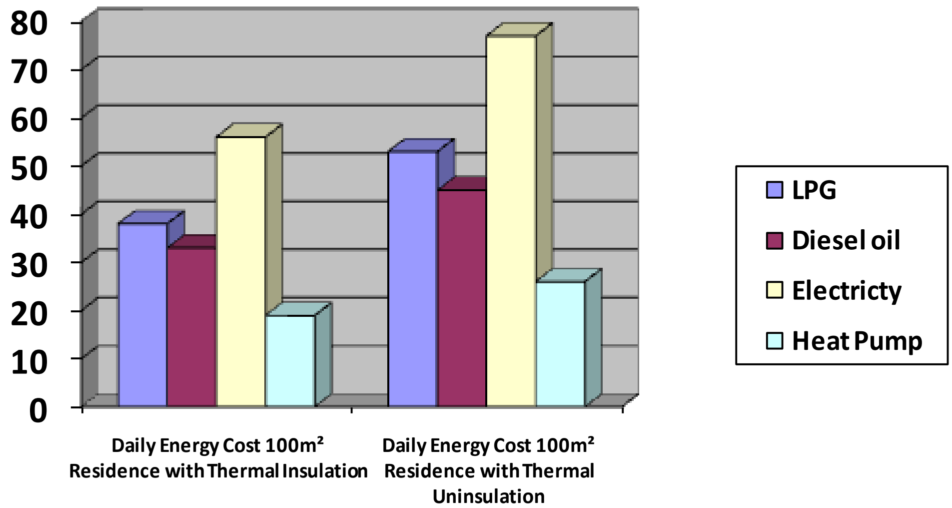

Chart 1: Daily Energy Costs of a Panel Radiator 100 m² Residence with and without Thermal Insulation

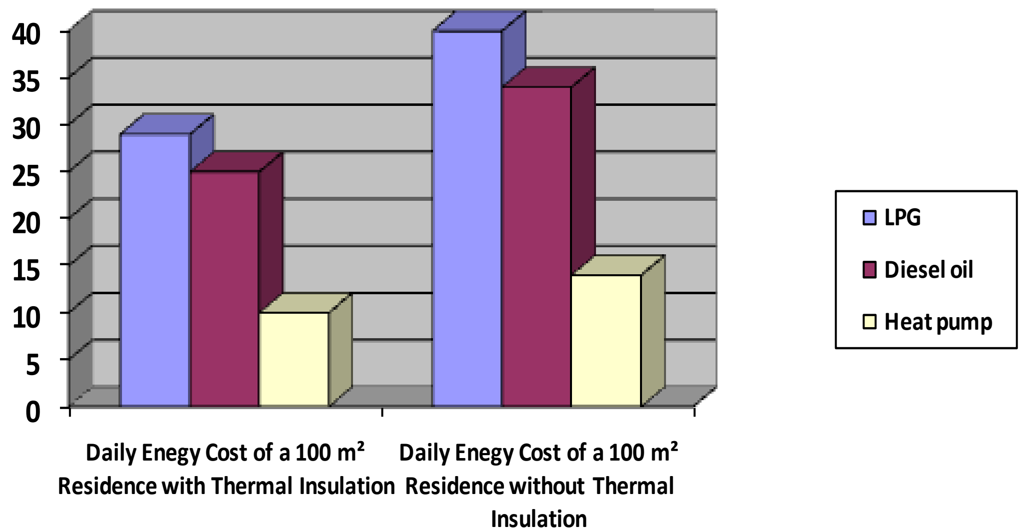

Chart 2: Daily Energy Cost Floor Heating System 100 m² Residance with and without Thermal Insulation

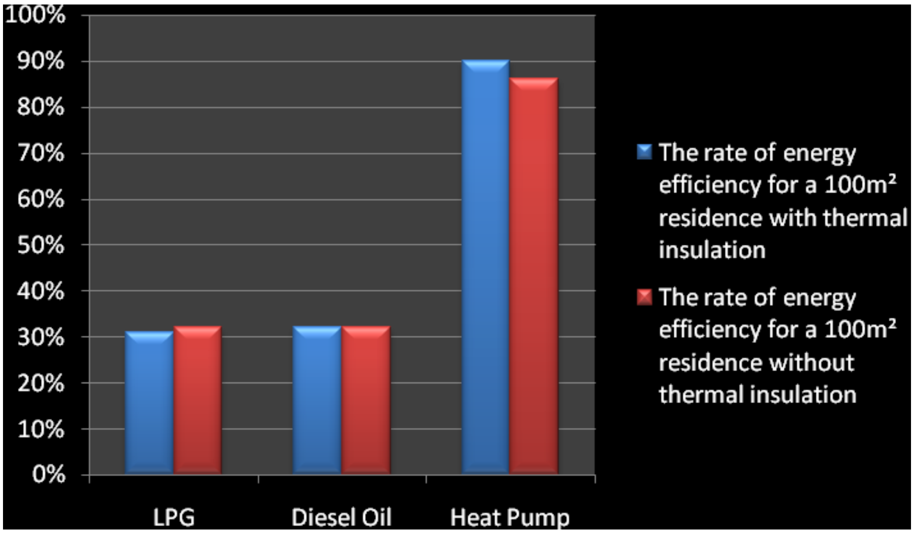

Chart 3: The Energy Efficiency rate of 100m² Residence with and without Thermal Insulation

In this chapter, the calculation of the COP (Coefficient of Performance) of the heat pump will be explain by the use of a figure. Additionally, by exploring the COP values of the currently used fuel types, the fuel type which uses the less energy will be determined.

The figure below demonstrates how the COP performance value of the heat pump is calculated.

η= Efficiency(used for boilers)

COP= Coefficient of performance(used for heat pumps)

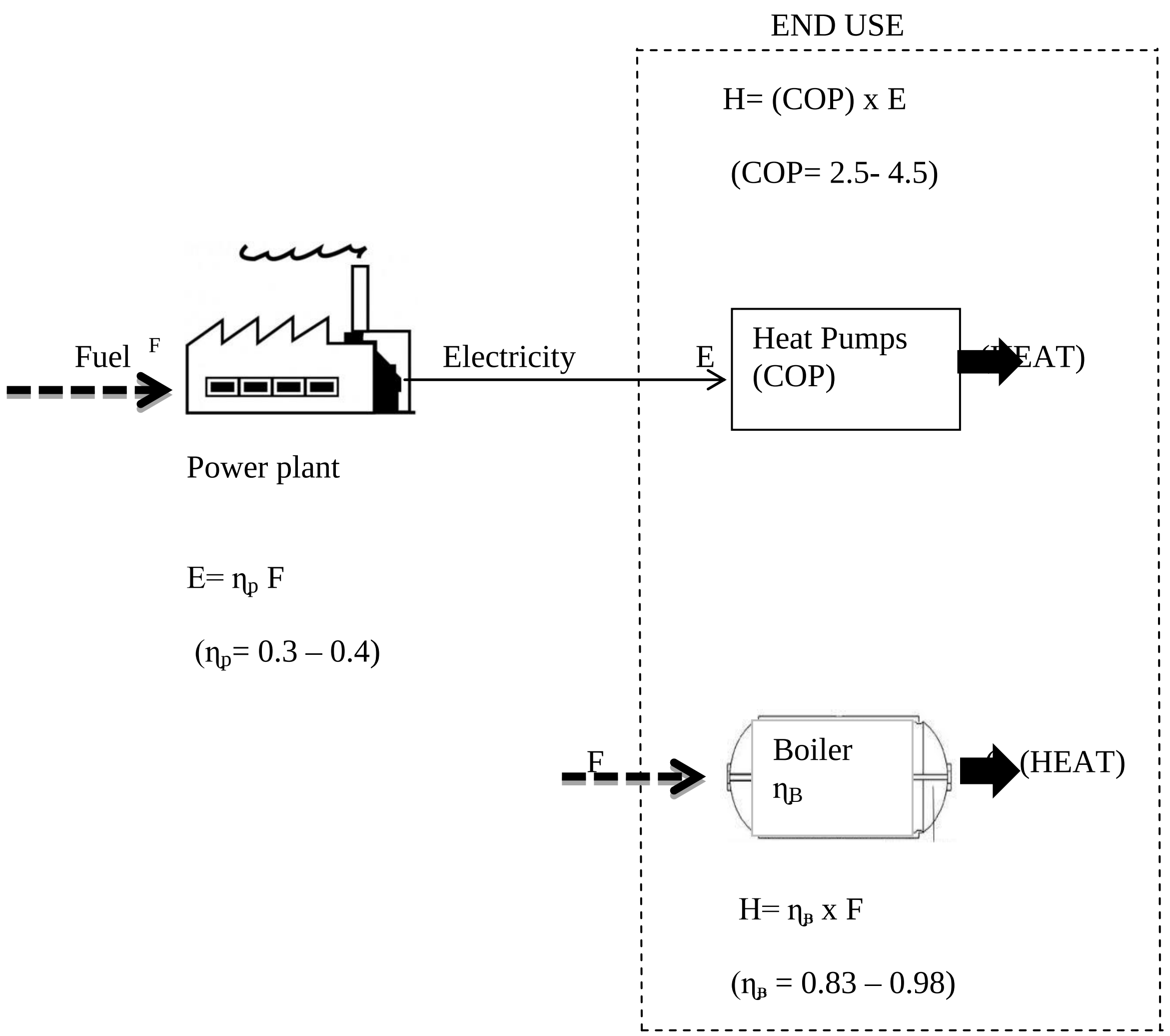

Figure 39: The Figure Demonstrates how the COP Performance Value of the Heat Pump is Calculate (by Author).

A Heat pump uses electricity to produce heat. The electrical energy used will be multiplied by a factor called coefficient of performance (COP) in order to obtain the heat supplied. The electricity in used from the mains grid system, implies that it corresponds the some fuel used in the central power units. Alternatively if a boiler is used for achieving central heating (or underfloor heating) the fuel is burned at the site. Both of these systems are shown in figure (Figure 39).

3.3 Evaluation of the Heating System in Terms of Application Techniques

The faults in the instalment of high-cost and difficult-to-apply heating systems result in imbalances in the room temperature, not-efficient heating or extreme heat. Additionally, as a result of the wrong application, potential environment-related problems may arise in relation to the low quality materials and low structure quality.

The rest of this section will refer to the issues that need consideration while installing radiator or underfloor heating systems.

The most important issue while installing radiator system is the direction of the instalment pipes. The installation pipes should be as short as possible and should be rotating at the minimum level while determining their direction. By doing this, the possible heat loss will be prevented and heating amount will be increased (Figure 40). With underfloor heating, as the heat loss is too much, more frequent pipes are placed at window fronts. The pipes used in underfloor heating systems should be easily-bendable, durable and impact-resistanct at temperatures lower than the freezing point. Additionally, the pipes used in underfloor heating systems should also be corrosion-resistant.

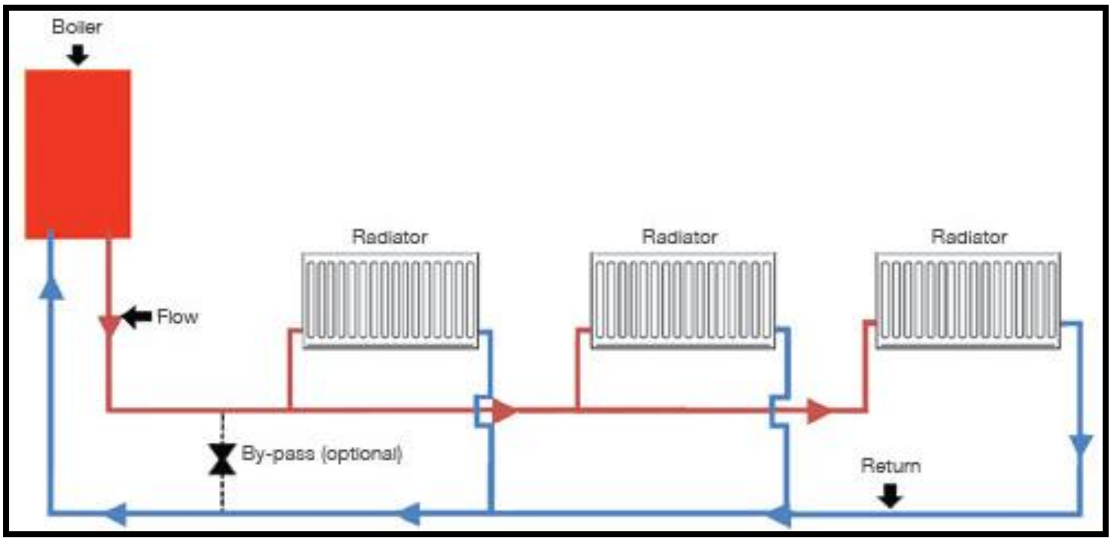

Figure 40: Radiator System Application (Dağsöz, 1998)

Radiators should be chosen based on the size of the space, amount of heat loss and usage conditions. Applying radiator more than needed in spaces is unnecessary and will cause excess heat; low radiator application, on the other hand, would cause insufficient heating.

Radiators transferred heat to spaces as heat convection and heat radiation. In order to prevent the heat loss escaping from the wall behind the radiator to the outside environment and to increase the efficiency of the system, insulation should be made between the wall and the radiator.

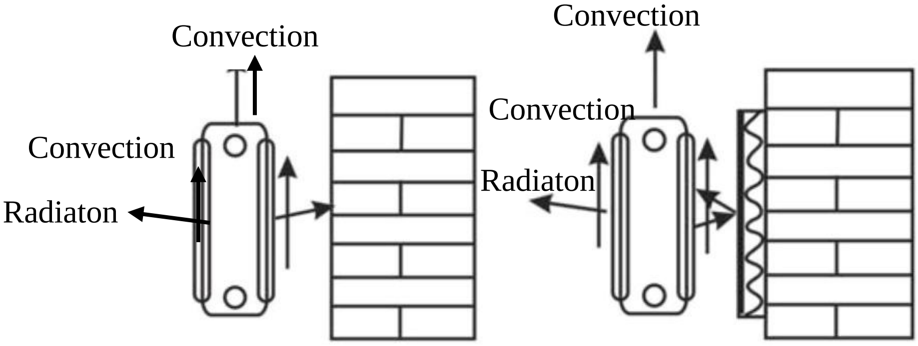

Figure 41: Radiator Wall with and withouth Insulation (Anonim, 2000)

In underfloor heating, the energy of the water in the pipes is transferred to the screed finishing around the pipe. In order to prevent any loss of the heat that reaches the flooring surface passing through the screed finishing caused by the walls and below the pipes; a well-done thermal insulation is required.

Evaluation

The majority of heat loss in buildings is caused by the windows. For this reason, the projects should be designed in a way which puts the radiators attached to the parapet surface under the windows. As the heat transfer is done through convection in radiators, it is important to leave an opening on top of the radiator to easily let the air of the setting in and out of the radiator for efficient heat convection when the radiators are placed on the walls.

The correct assembly spot is chosen and the radiator is install to the exterior wall and under the window in (Figure 42). In such an application, the temperature difference between the flooring and the ceiling is almost non-existent. As the temperature is homogeneous, an air stream will be formed and the heat distribution in the radiators will be almost ideal and healthy. The cold air around the leg and feet area of the residents will be contacting the hot air from the radiator and as a result it will heat up and rise as well. Thus, the setting air will be heated homogeneously (Anonim, 1997).

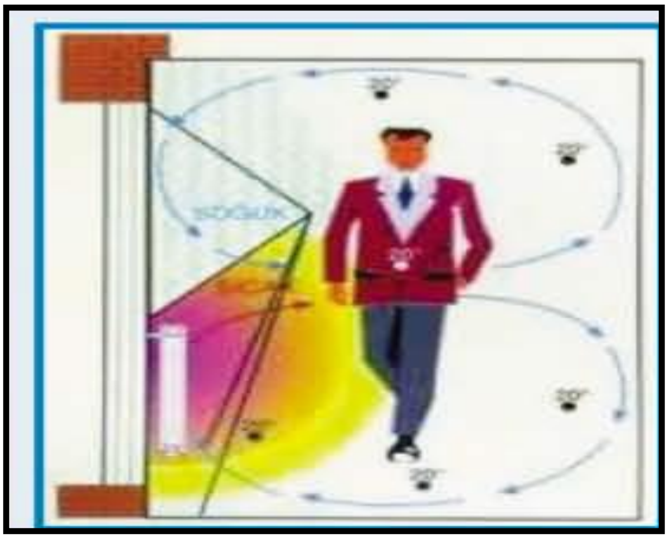

Figure 42: Radiator System Correct Application
(Anonim, 1997)

The application method in (Figure 43) is wrong. In this figure, the radiator is install to the inner wall in the space. The area with the radiator attached to the inner wall in this wrong application will be very hot and very cold toward the exterior wall. This difference in temperature will rapidly create an air stream in the space and a sense of cold on the legs and feet will be inevitable (Anonim, 1997).

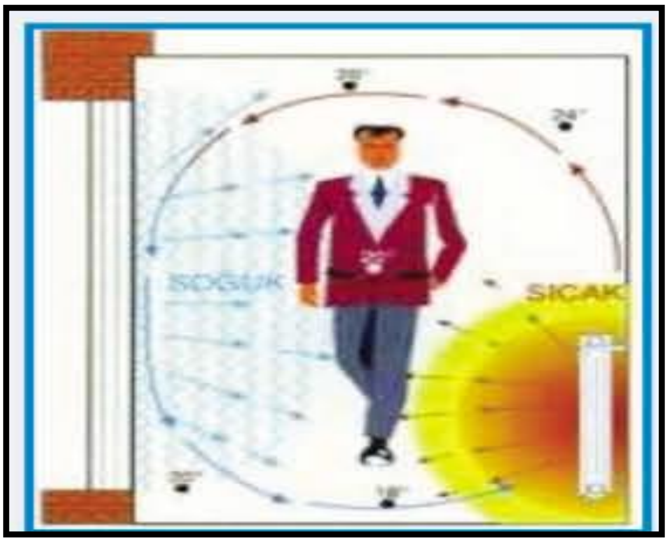

Figure 43: Radiator System Wrong application
(Anonim, 1997)

When the applications shown above are compared: a correct radiator application provides a comfortable setting as well as efficient heating.

More frequent and less spaced pipes should be applied in underfloor heating systems to the wall corners at north; window corners because the loss of cold and heat is at high levels at these spots (Figure 44). Thus, it is prevented to have spots with different temperatures within the inner space and a comfortable setting is offered as well as efficient heating (Anonim, 2007).

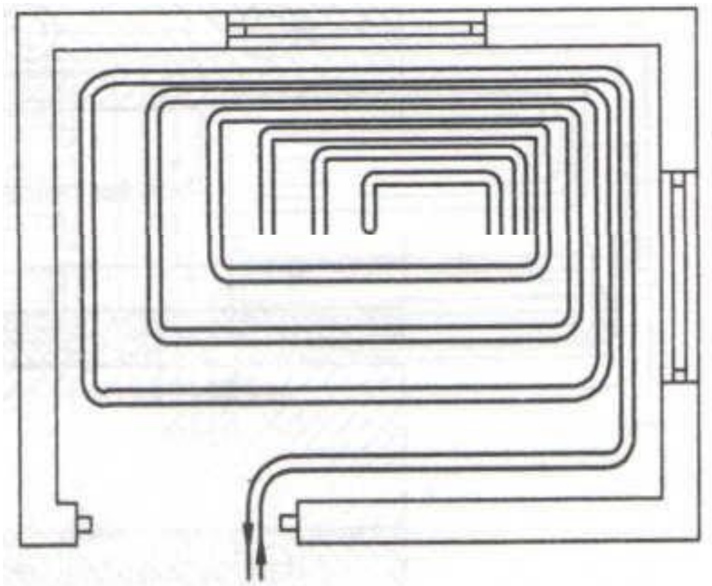

Figure 44: Floor Heating Application Detail
(Anonim, 2007)

The most important point to consider in system applications is the quality of the pipes and their durability. The pipes transferring heat are the most important components in such systems. The quality of the pipes under the flooring and the connectors should be very high. Otherwise, it is very difficult to replace the pipes in case of any malfunctions in the heating pipes and it will cause high amount of fixing costs. Therefore, the attention paid in the installation process does not only make the system more durable but also prevents any possible malfunctions in the future.

Another important detail in radiator and underfloor heating system applications is whether they can be set at construction stage or while the building is used. Radiator application can be done when the building is used even though, it is a long process. However, underfloor heating system is very difficult to apply when the building is being used. Such a procedure can only be done if the floor level is suitable. On the event of application, removing the flooring will both take time and bring extra costs.

The pipes used in radiator and underfloor heating systems should be durable, impact resistant to temperature below freezing point and corrosion-resistant. With the correct application, the floor heating systems have a lower rate of leakage, rusting and malfunction compared to the other systems.

Chapter 4

CONCLUSION

According to my literature research, heating systems have been evaluated in 3 parts like thermal comfort, energy efficiency and application technique.

The need for energy is increasing day-by-day in today's world. In order to meet this increasing need; it is being tried to make use of renewable energy resources such as solar, wind and geothermal energy as well as trying to make use of the limited underground resources. The energy produced by using underground resources is getting expensive day-by-day and it is pushing country's economy due to being limited. Producing energy from resources like the sun and wind may seem expensive now, but they will be less costly in the future compared to the renewable energy resources like petrol and natural gas due to the foreseen scarcity of these resources.
The energy expenses which are a big burden for economies of the countries can be reduced by producing low-cost energy but more importantly, it can be reduced with energy saving. Energy efficiency is an important issue in today's world as a significant amount of energy is consumed in buildings for comfort needs. For this reason, it is crucial to structure the heating systems used in buildings to provide thermal comfort in a way that uses energy efficency.

The present study evaluated the radiator and underfloor heating systems in three sections: Thermal comfort, energy efficiency and application techniques.

The result of these evaluations;

Underfloor heating systems are able to provide a more comfortable inner-space compared to radiator systems as the heat distribution in the room is homogenous and sudden decreases in the outside temperature do not affect the underfloor heating systems.

As the radiator does not provide a homogenous thermal comfort in a heating environment; it was seen that underfloor heating in which the whole flooring is a heating element, are able to provide a more homogenous thermal comfort at different spots of the setting. As a result of these findings, it is possible to come to the conclusion that underfloor heating systems are more capable of providing a more homogenous thermal comfort setting compared to radiator heating systems.

The maximum floor comfort temperature is limited to 25°C in underfloor heating. The maximum floor temperature is usually taken under consideration at the project designing stage. However, objects placed on the floor like carpet or furniture cause decrease in floor temperature and heat load. In radiator systems; covering the front of the radiator with furniture, closing the top of the radiator with decorations or curtains may cause a low-temperature feeling.

In order to create a balance in the inner setting temperature, the room temperature can be controlled through different methods such as setting the thermostat to room temperature, to outside environment temperature, to the temperature of the hot water in the water tank or changing the water flow.

As the underfloor heating systems are used at lower values than the radiator systems, they have less dust movement. This feature makes the underfloor heating system more suitable for general health conditions as well as people respiratory system problems such as asthma.

Additionally, the as the floor temperature is at 25°C, this prevents the formation of vascular diseases. However, when the temperature goes above 29°C due to misapplication or misusage, it may cause swelling in the feet or varicose. Along with this, the high temperature on the flooring in underfloor heating systems reduces the moisture amount and thus, creates a negative environment for creatures like mould, bacteria, virus or mite.

Radiator systems can heat-up the environment they are set at a short period of time after initiating. Underfloor heating can provide comfort temperature after a few hours of initiation. It heats-up and cools-down a couple of hours late. By taking this into consideration, underfloor heating is not suitable for residences like summer house where you only spend a day or residences that require heating only for short periods of a day; rather, it is suitable for residences that are used for 24 hours.

The places where the heat loss is dense are the window fronts. For this reason, radiators should be placed at windown fronts and underfloor heating pipes should be more frequent at these spots.

The building isolation that these systems will be applied to should be very good. If the building isolation is not good, the system will be operated at high temperatures which in turn, will increase the operation costs.

The flooring material and its thickness are the most important factors that affect performance. The heat transmission in floor heating systems is controlled by the thermal resistance of the structure component with low heat transfer coefficient on the top level. It is required to apply flooring material with heat transmission coefficient in such situations. If the flooring material applied does not have a low heat transmission coefficient, the heat resistance anticipated in the project will have to be increased. The ground temperature will go above the standard temperatures and will negatively affect the thermal comfort.

While the operating temperature of water is 90-70°C in radiator heating systems; the inflow temperature in underfloor heating systems is 50-45°C. Thus, the system allows choosing the heating fluid in lower temperatures and this both reduces the operating cost and energy efficiency. The heating cost of underfloor heating systems is lesser compared to the radiator heating system because the temperature change along the height within the room and the comfort temperature is low.

When the underfloor heating systems are compared to the radiator heating systems in terms of set-up cost, operation cost and energy efficiency, the underfloor heating systems are more economical. These systems pay back their set-up cost within a year and a half or 2 years. With the correct applications, they can work for 10-20 years without any problems. The systems become more durable with periodical maintenance and quality material application; and this prevents any possible malfunctions. However, as a result of no periodical maintenance or the system is applied in a wrong way by the companies, the fixing of malfunctions and replacing it is difficult and highly costly.

In addition to this; underfloor heating systems have more advantages compared to radiator heating systems in terms of using solar energy and geo-thermal energy; because the circulation water in the underfloor heating instalment is at lower temperatures than the water in the radiator systems.

This study will set an example for the correct application and usage of the country's energy efficient systems and contributes to the increase in the interest toward energy efficient systems. It is obvious that there are only a few local studies and applications in the literature on this topic and this study will contribute to that gap. Additionally, this study will also contribute to the companies using and applying these systems in terms of correct use and application.

Table 16: Parameter

System Types	Investment Cost	Annual Energy Cost	Comfort Level	Approx. System Efficiency	Maintenance and Operation MCO cost(annual)	Application Techniques	Other Remarks	Floorcovering
Central Heating Radiator System (Gas)	The investment cost for radiator systems are low	Highest annual energy cost	Radiator heating does not perform ideal thermal comfort	Low energy efficiency	They require maintenance at certain periods. High annual operation cost	These systems are easy to apply. They can easily be applied to any space	It is not appropriate for using renewable energy resources as the heater fluid temperature is at high levels.	They are used for all kinds of upper floor material
Central Heating Floor Heating (Gas +Solar)	The investment cost for floor heating systems are high.	Low annual energy cost	Floor hearing perform the most ideal thermal comfort for human thermal comfort	High energy efficiency	No need for maintenance. Low annual operation cost.	These systems are difficult to apply. It shouldn't be applied at space used for short periods or summer houses	They are the most appropriate systems for using renewable energy resources as the heater fluid temperature is at low levels	Stone and ceramic are the most suitable upper floor materials for floor heating as they are good at thermal conduction and can hold heat for long periods. Marble floor-houses require more energy to hold the heat and keep the house warm. Carpet and wood floors have the lowest heat transfer coefficient
Central Heating Heat Pump (Electric)	The investment cost for Heat Pump systems are low	Lowest annual energy cost	Heat Pump does not perform the ideal thermal comfort	Highest energy efficiency	Requires constant maintenance. Low annual operation cost	These systems are easy to apply. They can easily be applied to any space	They are the most appropriate systems for using renewable energy resources	They are used for all kinds of upper floor material
Central Heating Heat Pump (Electric+Solar)	The investment cost for Heat Pump systems are low	Lowest annual energy cost	Heat Pump does not perform the ideal thermal comfort	Highest energy efficiency	Requires maintenance at certain periods. Low annual operation cost.	These systems are difficult to apply	They are the most appropriate systems for using renewable energy resources	They are used for all kinds of upper floor material

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