An-Najah National University
Faculty of Graduate Studies

Comparative Study for Underfloor Heating System using Boiler or Heat Pump

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This thesis was defined successfully on 15/2/2014, and approved by:

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3. Dr. Mohammad Al-Sayed / Internal Examiner	....

DEDICATION

To my father soul ….

To my mother, brothers and sisters…….

To my wife, daughter……

To my uncles & Grand Father……

To all friends and colleagues………

To everyone working in this field……

To all of them, I dedicate this work.

ACKNOWLEDGMENTS

It is an honor for me to have the opportunity to say a word to thank all people who helped me to complete this study, although it is impossible to include all of them here.

All appreciations go to my supervisor, Dr. Abdelrahim Abusafa for his exceptional guidance and insightful comments and observations throughout the implementation of this project. My thanks and appreciations go to the staff of Clean Energy and Conservation Strategy Engineering Master Program in An-Najah National University, especially Dr. Imad Ibrik, Prof. Marwan Mahmoud & Dr. Mohammad Sayed for their valuable suggestions and assistance.

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Hussein I. Awad.

الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Comparative Study for Underfloor Heating System using Boiler or Heat Pump

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Abbreviations

A	Area (m^2)
A_f	Floor Area (m^2)
ASHREA	American Society of Heating, Refrigerating and Air Conditioning Engineers
COPHP	Coefficient of Performance for Heat Pump
ΔTw	Temperature Difference(˚C)
COP	Coefficient of Performance
Cp	Specific Heat at Constant Pressure (J/kg.˚C)
CHP	Combined Heat & Power
DHW	Domestic Hot Water
DCF	Discounted Cash Flow
DN	Do Nothing
DIN	German Institute for Standardization
DD_H	Degree Day Method for Heating.
DCF	Discounted Cash Flow
EN	European standard
HFC	hydro-flouro-carbons
HE	Heat Exchanger
IEA	International Energy Agency
K	Thermal Conductivity (W/m. K)
Mw	Mass flow rate of water (kg/s)
MARR	Minimum Attractive Rate of Return
NPV	Net Present Value
ODP	Ozone Depletion Potential
P	Pressure (Pa)
PW	Present Worth
PER	Primary Energy Ratio
Qe	Heat Emitted by the pipe (W).
q_l	Heating Load for the Floor (W/m^2).
ROI	Return on Investment
ROR	Rate of Return
T_k	Floor Temperature (˚C)
T_L	Floor Surface Temperature (˚C)

T_i	Inside Design Temperature (˚C)
T ambient	Ambient Temperature (˚C)
TEWI	Total Equivalent Warming Impact
Tw,s	Water Supply Temperature (C)
T_{bal}	Balancing Temperature (C)
UFH	Under Floor Heating (˚C)
Vw	Flow Velocity (m/s)
W	Work (J)
WBCSD	World Business Council for Sustainable Development
ρ_w	Water Density (kg/m^3).
$\zeta_{H/E}$	Heat Exchanger Efficiency
ζ boiler effic.	Boiler efficiency

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Comparative Study for Underfloor Heating System using Boiler or Heat Pump

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Abstract

Energy savings are an important issue for both economy and environment. Domestic and residential buildings heating systems are known of their high energy consumption and high environmental effects. The main goal of this study is to compare between electrical heat pump and diesel boiler for feeding under floor heating loops. A case study of a typical residential apartment (78.3 m^2) is selected to compare its heating energy requirement when using either an electrical heat pump or diesel boiler with under floor heating system at similar comfort quality conditions.

The heating load is calculated for the apartment based on the variation of the ambient temperature in winter months –November, December, January and February - during two years (2011 - 2012), through meteorology data obtained from Palestinian Meteorological Department for Hebron City. An empirical coefficient of performance (COP) for the heat pump is used. The used equation takes in consideration both the heated water and ambient temperatures. The obtained monthly heating energy was also calculated using the degree day method (DDH) , moreover the expected seasonal diesel consumption was calculated using DD_H method, and found to be similar to that calculated by heating load method.

The maximum calculated heating load is 6.11 kW based on the average minimum ambient temperature of 7 ^{o}C, and the corresponding COP of the heat pump was 3.13.

A simple economical analysis using the present worth value shows the superiority of the heat pump over the diesel boiler. The annual cost of the heat pump is about 2000 NIS while it is about 7000 NIS for the diesel boiler. These calculation was performed based on equal life time for both systems of 15 years.

The environmental effects of both systems was compared based on the carbon dioxide emissions, the results show slight deference between both systems. Annually, 31.2 tons of CO_2 emissions is expected from the heat pump while 33 tons of CO_2 is expected from the diesel boiler, this could be due to the use of coal for electricity generation in the region.

Chapter One

Introduction

Chapter One
Introduction

1.1 Introduction

There are many different types of standard heating systems. Central heating is often used in cold climates to heat private houses and public buildings. Such a system contains a boiler, furnace, or heat pump to heat water, steam, or air, all in a central location such as a furnace room in a home or a mechanical room in a large building. The use of water as the heat transfer medium is known as hydronics. The system also contains either ductwork, for forced air systems, or piping to distribute a heated fluid and radiators to transfer this heat to the air. The term *radiator* in this context is misleading since most heat transfer from the heat exchanger is by convection, not radiation. The radiators may be mounted on walls or buried in the floor to give under-floor heat. [1]

In boiler fed or radiant heating systems, all but the simplest systems have a pump to circulate the water and ensure an equal supply of heat to all the radiators. The heated water can also be fed through another (secondary) heat exchanger inside a storage cylinder to provide hot running water [1,2].

Forced air systems send heated air through ductwork. During warm weather the same ductwork can be used for air conditioning. The forced air can also be filtered or put through air cleaners [3].

Heating can also be provided from electric, or resistance heating using a filament that becomes hot when electric current is caused to pass through it. This type of heat can be found in electric baseboard heaters, portable electric heaters, and as backup or supplemental heating for heat pump (or reverse heating) system [3].

The heating elements (radiators or vents) should be located in the coldest part of the room, typically next to the windows to minimize condensation and offset the convective air current formed in the room due to the air next to the window becoming negatively buoyant due to the cold glass. Devices that direct vents away from windows to prevent "wasted" heat defeat this design intent. Cold air drafts can contribute significantly to subjectively feeling colder than the average room temperature. Therefore, it is important to control the air leaks from outside in addition to proper design of the heating system.

To keep uniform Heat Transfer distribution to the desired condition space, heat must be given to the circulating water; to distribute hot water to pipes loop under the floor, heat must be released out from the floor surface, since hot air is normally transferred from the bottom of the space to the top[3].

In a situation where to replace internal environment heating system, undertaking renovation, or building from scratch, then under floor heating is something to consider. There are several advantages; it gives a very even temperature over the floor area, with very few cold spots. Because the floor temperature is much lower than a conventional radiator, convection currents are minimized and there are less draughts. Efficiently installed, it should run at 35 degrees Celsius for water, compared to radiators which run at 75 degrees [1].

The radiant heat given off by the floor results in very high comfort levels. From practical point of view this means that, it's possible to run this system at lower temperatures to so save energy. There will be no radiators taking up wall space. Under floor heating works well with a condensing boiler because the boiler runs more efficiently with low return temperatures.

However, the main disadvantage of under floor heating is that it is slow to respond and can take a long time to heat up. So it is best used in homes or buildings that will be in use for fairly long periods, but the ground source area in this case is considered as a heating storage element due to heat transfer lagging to the air inside the room.

In This research the comparative study aims to clarify the advantages & disadvantages for using both Heat Pump and Boiler alternatives to supply the under floor heated area, and demonstrate the feasibility behind replacing Diesel Boiler with Electric Heat Pump.

1.2 Objectives of the study

1- Sizing of HP for a typical Heating Load, using the Under Floor Heating Media.

2- Compare both underfloor Heating Systems based on Electric Heat Pump or Diesel Boiler, compare the Coefficient of Performance

(COP), amount of diesel consumption under variable temperature input.

3- Study the effect of heating load and ambient temperature on the Coefficient of Performance.

4- Perform simple economic analysis for both systems

5- Perform an environmental impact assessment for both system using the carbon footprint

1.3 Methodology of the Study

Use of under floor heating is due to the high efficient of heat transfer and distribution in the desired space, so the ability to maintain the space in the comfort zone (21 C° , □=50%) can be achieved more than any system [1].

The normal direction of heat convection can handle the heat from the hot surface (Ground) to keep regular hot air distribution during the time.

Diesel boiler is the heat source that is normally used for heating, steam production and domestic hot water. But, this system has to be compared economically to clarify the feasibility to be used in the heating issues, so heat energy sources must be found to cover such loads. The high coefficient of performance "COP" of heat pump trigger to use it in heating.

The system consists of a heat pump chiller, heat exchanger, storage tank, circulating pumps (duty & stand by), expansion tank, pressure regulator, strainer, pressure gauge, thermometer, shut off valves, pumps controller for standby operation, water collector for distribution with individual valves, internal tubes loops.

Heat is gained from the condensing gas on the condenser unit, and normally inter the heat exchanger to get domestic hot water from the storage tank, the remaining amount of water must pass through the collectors to distribute the hot water to the loops with specific calibration.

Sizing of an Under Floor Heating System using the Heat Pump as the Main Heating System & Diesel Boiler as an auxiliary System and build the Mathematical Model to study the Effect of changing the ambient temperature on the indoor temperature, then we can get the relations between these variables.

COP = Desired Heating Load / Required Input Power [1]

The idea in using the under floor heating is to use the ground as a heat storage elements, at the day time when the COP of the system is maximum and to use this storage heat at night when the COP is going down due to the low ambient Temperature.

The water temperature used in under floor heating is produced efficiently from heat pump unit. Which means, no special arrangements or techniques in the basic system, the components of the system will be designed according to the existing conditions, Simulation procedure will be done using Excel.

An important target will be accomplished by using the Electric Heat Pump Unit in parallel with the diesel boiler, because many under floor heating installations in residential building in Palestine are depending on diesel boiler as a heat source due to diesel price before 15 years, so it's a problem to turn off diesel boilers and put them as a scrap due to the rabid rising for diesel prices, so the concept of Hybrid operation is normally available in this case, we can satisfy the owner in the more feasible operation mode during the winter time.

The relation between the ambient temperature & Power input to the system will be studied to select the optimum operating mode for the whole system.

Chapter Two

Under Floor Heating Analysis & Calculations

Chapter Two
Under Floor Heating Analysis & Calculations

2.1 Introduction

The idea of using the floor as a heat emission surface goes back over two thousand years. Heating systems inspired by this idea were built by the Chinese, Egyptians and Romans. The system adopted by the Chinese and the Egyptians was fairly simple. It consisted of building an underground hearth and sending smoke under the flooring of the rooms to be heated; it was in practice single room heating. The Romans, however, used far more complex advanced systems. Using the smoke from a single external hearth, they were able to heat several rooms and even several buildings, thus achieving the first central-heating type system. However, it was not until the start of this century that under floor heating appeared in its present form. It was an Englishman, Professor Baker, who was first to patent this type of system using the title "systems for heating rooms with hot water carried by under floor piping. [4]

In the early years after World War II, there were two main reasons for the spread of panel heating. These were the constant unavailability of heat emitters and the ease of insertion of the panels in prefabricated floor slabs.

The technique used consists of burying 1/2" or 3/4" steel tubes in the flooring, without overlying insulating materials. In Europe, from 1945 to 1950, over 100,000 homes were heated by this technique. Later, however, it was noted that the equipment was causing numerous physiological problems, such as poor circulation, high blood pressure, headaches and excessive sweating. Problems of this nature were so serious and well-documented that certain European countries set up Commissions to identify the causes.[5]

The results of the various Commissions of inquiry agreed that, in the systems constructed, the physiological problems were due to two values being too high:

a. The surface temperature of the flooring.

b. The thermal inertia of the floor slabs.

It was demonstrated in particular that, in order to avoid feelings of discomfort, the floor temperature should not exceed 28-29°C. In fact, in the systems examined, far higher temperatures were found, even in excess of 40°C. It was also demonstrated that the excessive heat accumulated

In the floor slabs of the systems meant overheating of the rooms above physiologically acceptable levels. The Commissions themselves, however, did not publish any negative judgments of panel systems. They demonstrated that these systems, if constructed for a low surface temperature and

Without excessively high thermal inertia, can offer heat comfort greatly superior than that which can be obtained with radiator or convector equipment. Whilst not being a condemnation, the Commissions results in fact constituted a strong disincentive to produce panel systems, and it was some years before they made any significant comeback. [5]

The event which again drew attention to these systems was the energy crisis in the 1970s. Under the impetus of this crisis, almost all European countries issued laws which required efficient heat insulation of buildings, and it was thus possible to heat rooms with less heat and so (in the case of panels) with lower floor temperatures.

In addition, in most cases, the degree of insulation required made it possible to heat the rooms with floor temperatures lower than the physiological maximum, and this in turn made it possible to reduce the thermal inertia of the system. A further reduction in thermal inertia was obtained by producing "floating" floors with heat insulation either under the panels or towards the walls. And it was precisely this innovation, of a legislative and technical nature, which finally made it possible to produce thoroughly reliable panel systems with a high heat output. Nowadays in Europe, the "new" panel systems are installed mainly in the Northern countries, where they are experiencing a deserved success, largely due to the advantages, which they can offer. [5]

2.2 Advantages of Panel Systems

The main advantages offered by panel systems relate to:

- Heat comfort.

- Air quality.

- Hygiene conditions.

- Environmental impact.

- The heat usable at a low temperature,

- Energy saving.

2.2.1 Heat Comfort

As the ideal conditions curve shown in Figure (2.1), in order to ensure comfortable heat conditions in a room, slightly warmer areas must be maintained at floor level and slightly cooler ones at the ceiling level. The system most suited to providing these conditions consists of radiating floors, for the following reasons:

1. The specific position of the panels.
2. The fact that they give off heat above all by radiation, thus avoiding the formation of convection currents of hot air at ceiling level and cold air at floor level.

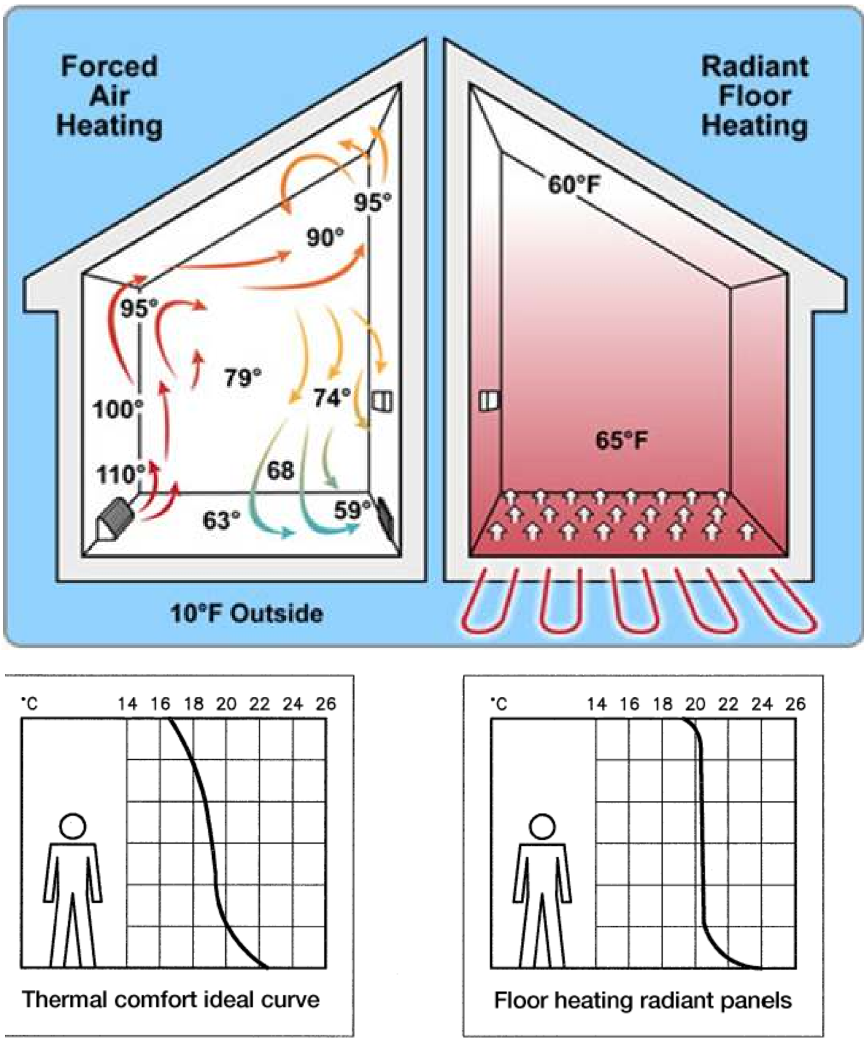

Figure (2.1): Thermal Comfort Curve.

2.2.2 Air Quality

Panel heating can prevent two inconveniences which are typical of systems with heat emitters:

1. Burning of the dust in the air, which can cause a feeling of thirst and irritation of the throat.

2. High dust circulation which (especially in rooms which are not regularly cleaned) can cause allergies and respiratory problems.

2.2.3 Health Conditions

Panel systems have a positive contribution to maintaining good environmental health conditions as they prevent:

1. The formation of damp floor areas, thus removing the ideal conditions for dust mites and bacteria.

2. The occurrence of moulds on the walls bordering the heated floors.

2.2.4 Environmental Impact

In new buildings panel systems have the least environmental impact because:

1. They do not impose any aesthetic requirements. The invisible nature of the panels is of great importance, especially when air-conditioning buildings of historic or architectural importance, where the presence of heater emitters can compromise the balance of the original spaces.

2. They do not restrict freedom of layout, thus allowing the most rational use of the available space.

3. They do not contribute to deterioration of plasterwork, wooden flooring and hardware.

   - Do not dirt the walls with convection stains.

   - They do not allow formation of damp at floor level.

- They considerably restrict cases of internal condensation, as they increase the temperature of the walls near the panel floor slabs.

2.2.5 Heat Usable At Low Temperature

Due to their high dispersion area, panel systems can use the heat-carrying fluid at low temperatures. This characteristic makes their use convenient with heat sources whose efficiency (thermodynamic or economic) increases when the temperature required is reduced, as in the case of:

- Heat pumps.
- Condensing boilers.
- Solar panels.
- Heat recovery systems.

2.2.6 Energy Saving

In comparison with the traditional heating systems, panel systems produce considerable energy savings, for two basic reasons:

1- The higher operating temperature, which permits (for the same ambient temperature) average savings varying from 5 to 10%.

2- The lower temperature gradient between floor and ceiling, which provides higher energy savings the larger and higher the rooms.

The following are also (although admittedly less important) reasons for energy savings:

- The use of low temperatures which reduces dispersion along the piping.
- The non-heating of the walls behind the radiators,
- The lack of convection movement of the hot air over glazed surfaces.

On average, panel systems, in comparison with traditional systems, produce energy savings of between 10 and 15%.

2.3 Disadvantages of Panel Systems

These relate mainly to aspects connected

(1) With the surface temperature of the floor.

(2) The thermal inertia of the system.

(3) Difficulties of a design nature.

2.3.1 Limitation Connected with the Surface Temperature of the Floor

The maximum allowed floor temperature for residing zones is (29 ^{o}C), while that for the edge zones (35 ^{o}C) to avoid conditions of physiological discomfort [1]. On the other hand according to the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHREA standards) the surface temperature for residing zones are as follows:-

- The maximum surface temperature is (29.4^{o}C) and the optimum is (27.5 ^{o}C for dry surfaces.
- For bathrooms and shower the optimum floor temperature is (33^{o}C).

These values make it possible to determine the maximum heat output (Q_{max}) which can be transferred by a panel.

Since the maximum floor temperature is 29^{o}C then the value of heat output by the floor should be equal or less than 100 W/m^{2}.

If Q_{max} is less than the required output (Q), there are two possible situations:

a. Q_{max} is less than Q only in a few rooms, in which case additional heat emitters, wall panels or additional concentrate loop at the perimeter of zone can be used. For example, Q_{max} can come from the panels and the remaining output from radiators.

b. Q_{max} is less than Q in all or most of the rooms, a traditional type system should be used.

2.3.2 Thermal Inertia and Method of Use of Systems

Panel systems are characterized by having a high thermal inertia as, in order to transfer heat, they use the structures in which the panels themselves are buried. In environments heated with a certain degree of continuity (and good insulation under the panels), the thermal inertia of the system no reviles problems and permits to:

- Good adaptability of the system to the external climatic conditions.
- Slowing down of functions, with system ‘on’ and ‘off’ times which are normally two hours.

On the other hand, in environments which are only heated for short periods such as weekend homes, the thermal inertia of the panel system has considerable phase variations between the starting times and the times of actual use. Thus in these cases, other heating systems should be used.

2.3.3 Disadvantages Linked with Design Aspects

Unlike the traditional systems with heat emitters, panel systems require:

- Greater commitment to determine project parameters. In fact, apart from the parameters required to determine the heat losses from the rooms, the design of panel systems also requires detailed knowledge of all the constructional information regarding the floors and floor slabs.
- More complex, laborious calculations, although due to the greater commitment, these can be considerably reduced with the use of computers.
- Less adaptation to variants during the work or when the system is completed, as it is not possible to add or remove panel portions, as is done with radiators.

2.4 Panel Containment Structures

These consist mainly of the floor (or solid foundation on the ground), the insulating material, the slab and the floor tiles.

2.5 Pipe Loops Configuration

Each room must be heated with one or more specific panels. This makes it possible to control room temperatures independently, without altering the heat balance of other rooms.

Three types of pipe loops configurations can be used as follows.

1- Single serpentine configuration. This method yield easy installation of pipes and it can be used for all kind of floor structures. Temperature variations on the floor surface are kept to minimum values within small area. The pipe layout can be easily modified to produce different energy requirements by changing the pipe loop pitch. The pipe loop arrangement of this method is shown in Figure (2.2) this configuration is used in residences and requires very flexible pipe.

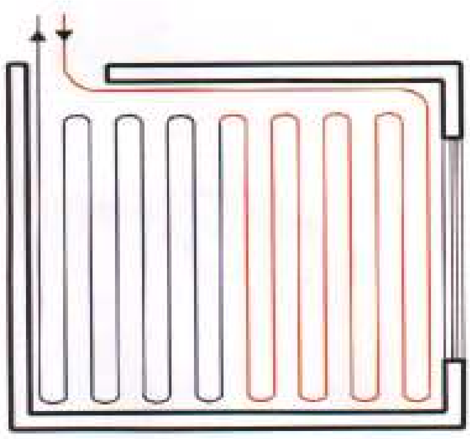

Figure (2.2) Single Serpentine Pipe Arrangement.

2- Helical supply and return configuration. This pipe arrangement is installed in a helical or spiral configuration as shown in Figure (2.3). This method is used in spaces that require high heating loads.

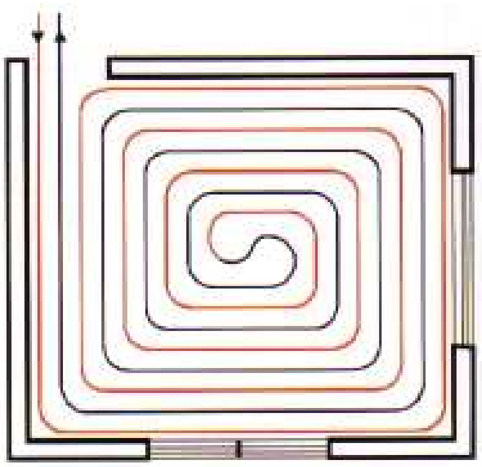

Figure (2.3) Helical or Spiral Pipes Arrangement.

3- Parallel supply and return pipes configuration. In this pipe arrangement, the supply and return pipes run in parallel configuration as shown in Figure (2.4). This pipe configuration gives uniform mean surface temperature but higher variation of floor surface temperature within small area. This method is used for heating large spaces such as mosques and theaters.

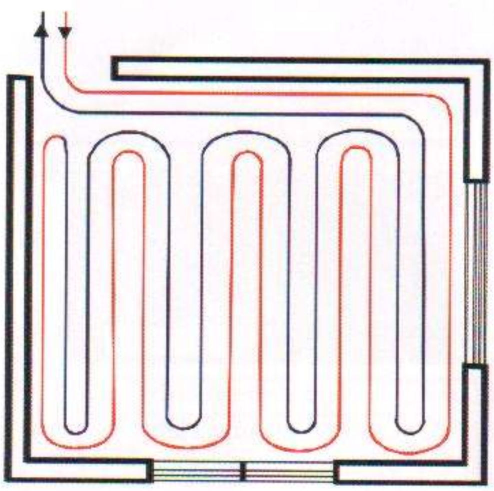

Figure (2.4) Parallel Supply and Return Pipes Configuration.

2.6 Panel Heating Design Parameters.

The design parameters that must be selected for the panels heating systems are as follows:

1- Pipe loop configuration. A single serpentine pipes and spiral configuration arrangement is usually used for residences of concrete floors. Parallel supply and return pipes configuration is used for heating large space lounges, theaters, etc.

2- Pipe diameter and pipe space. Different pipe spaces and diameters can be used. Based on economic aspects, required floor temperature and required heat flow from the pipes.

The panels can have constant or variable center-to-center distances with pipes closer together where there are areas of glass or highly dispersive walls as shown in Figure (2.5).

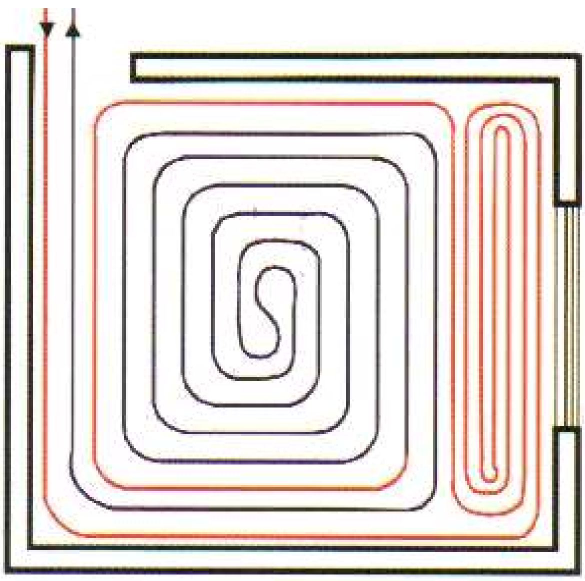

Figure (2.5) Panels with Variable Center to Center Distances.

3- Circulation of water temperature. The limitation on water temperature are to ensure that:

a. Surface temperature is in limits.

b. Screed temperature is also in limit. (DIN standards required that the temperature of cement screed to be less than 60^{o}C to avoid the thermal stress.

The design water temperature used in water flowing through PEX plastic pipe is usually 45^{o}C. on other hand ASHRAE standard required that the maximum water temperature in floor heating is 54.4 ^{o}C. And there is no rigid limitation on the drop of water temperature in the loop. However, an optimum design value is 5-8 ^{o}C.

4- Pipe depth. A pipe depth of 50 mm is usually used. In concrete floors, a pipe depth that ranges between 30 to 70 mm is recommended.

2.7 Under Floor Design.

The design procedure for under floor heating system is summarized as follows.

(1) Calculation of the heat load for each space.

(2) Calculation of the heat flux (W/m^2) by dividing the heat load for the required space by total floor area of the space.

$$q_L = \frac{Q_L}{A_f} \qquad \text{Eq. (2.1)}$$

(3) Evaluate of the floor surface temperature (T_k).

(4) Calculation of required pipes spacing and water temperature with considering the floor temperature and the tiles and floor types (ceramic, mosaic, cement, oak,…. etc).

(5) Limitation of the spaces between the pipes that will give the required floor temperature at selected water temperature.

(6) Calculation of the reverse heat flow since there is a cold surface on the other side of the heating pipes.

(7) Calculation of the total heat load to be emitted by the pipes (Qe).

(8) Calculate of the mass flow rate of water for each loop.

(9) Selection of pipe diameter with considering the flow velocity.

(10) Calculation of pressure drop for the longest pipe loop and the pressure drop due to the bending.

(11) The pump of the under floor heating system is selected from the manufacturer catalogues by using the total pressure drop of the longest pipe loop and the total water flow rate for all loops.

(12) Balancing the pressure drop for all pipe loops such that each pipe loop will have the same total pressure drop of that of the longest pipe loop. This is done by controlling the lock shield valve in the return manifold of each loop. This balancing is necessary to circulate the calculated value of water flow rate for each loop.

(13) Boiler selection by using the total Qe for all loops and domestic hot water.

2.7.1 Calculation of the Heat Load For Each Space

The heat load for space calculation is given in Chapter 4.

2.7.2 Calculation the heat flux

In order to be able to ensure conditions of physiological well-being, the heat output transferred by the panel must not exceed the maximum output

Where:

q_{max} = 100 W/m^2 in continuously occupied environments;

q_{max} = 150 W/m^2 in bathrooms, showers and swimming pools;

q_{max} = 175 W/m^2 in perimeter areas of rooms rarely used.

If the heat output required (q) is greater than q_{max}, a heat output less than or equal to q_{max} must be emitted by the panel and the remaining output made up by an integrated heat emitter or additional loop in perimeter.

2.7.3 Evaluation of the Floor Surface Temperature (TL)

The first step in designing under floor heating is calculation of the required surface temperature that will give the required heat flow to the spaces .

According to the DIN method the total heat output is considered to be nearly twice that of the convection , hence

$$q_L = 8.92(T_L - T_i)^{1.1} \qquad 2.2$$

$$= 8.92 * (29 - 20) = 100.007 \ (W/m^2).$$

Where :

q_L : Heat output per unit area (W/m^2).

T_L : Floor surface temperature.

T_i : Inside design temperature.

And the optimum inside design temperature for the room atmosphere is between 20-24 ^oC

2.7.4 Calculation of Required Pipes Spacing and Water Temperature

The next step after finding the required floor surface temperature (T_L) is to find the required pipe spacing (S) and water temperature (T_k) to obtain that (T_L). Figure (2.6) explain the relation between floor temperatures and water temperatures and pipes space for Ceramics floor which is used in Jordan .

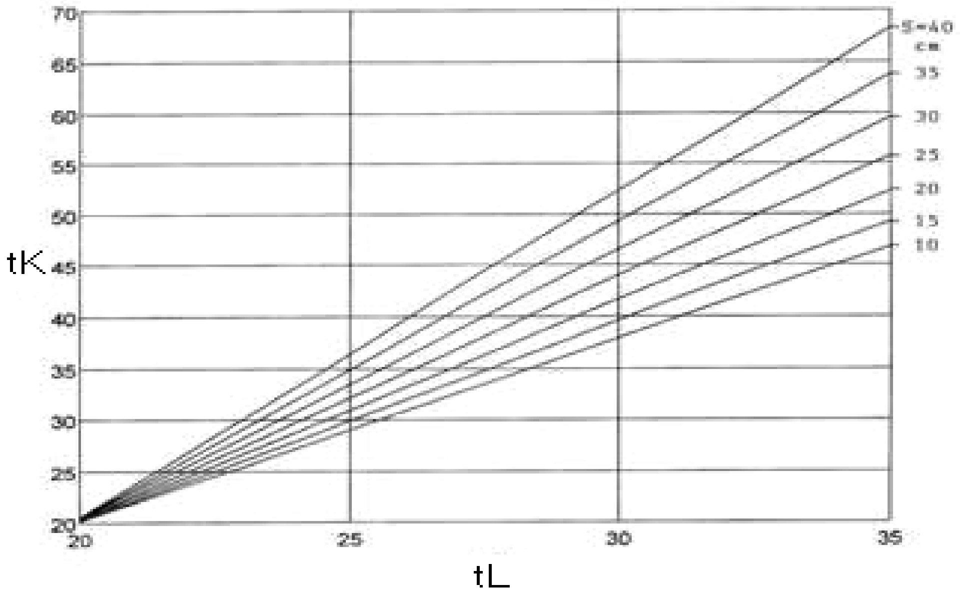

Figure (2.6) Spacing and water for Jordanian materials with Ceramics floor.[2]

2.7.5 Calculation the Reverse Heat Flow

Since there is a cold surface on the other side of the heating pipes then a reveres heat flow occurs. A rough estimate of the reverse heat flow is that it is 10% of the supplied energy for ceiling heating and 25% of the supplied energy for floor heating when poor insulation is used. If the reveres heat flow is to ambient atmosphere or to ground then it is thought of as losses else, it can be thought of as another heating source to the other space.

The reverse heat flow is in two modes: conduction and radiation. To reduce radiation. A reflecting aluminum sheet is placed on the top of the insulation. If such technique is not used, the heat loss by radiation cannot be neglected. The aluminum sheet has another main task to distribute screed temperature in-between heating pipes evenly.

Figure (2.7) show the relation between q_k and floor temperature for using 5 cm polystyrene insulators thickness.

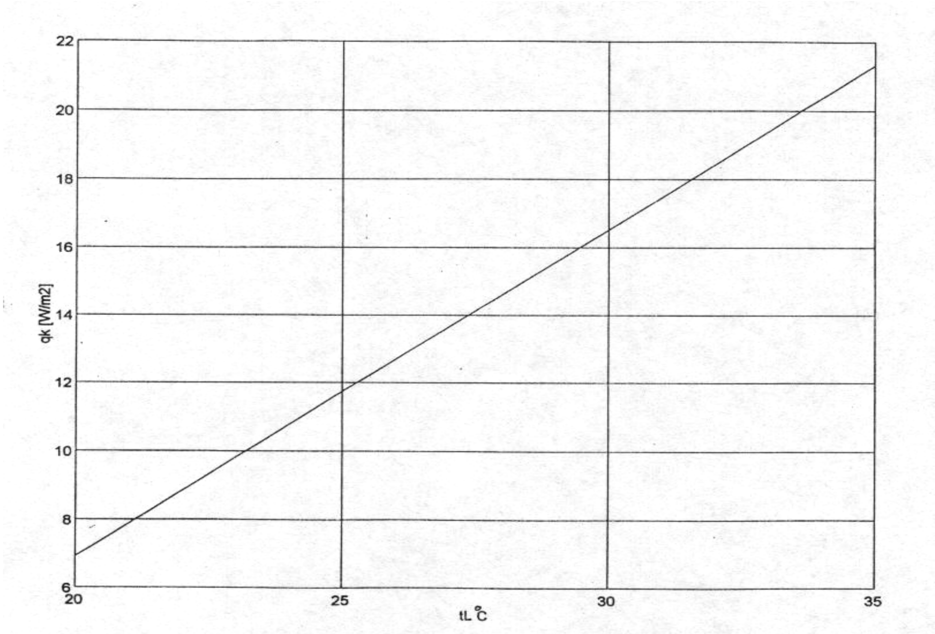

Figure (2.7) : Reverse Heat Output Versus (T_L) Using 5 cm Polystyrene.[2]

2.7.6 Calculation the Total Heat Load to be Emitted by the Pipes (Qe)

The total heat load must be emitted by the pipe is given by the following Equation:

$$Q_e = (q_L + q_k) \times A_f \qquad 2.3$$

2.7.7 Calculate the Mass Flow Rate of Water for Each Loop

After calculating T_k and q_k it is needed to find the volumetric flow rate of water in the heating pipe by using the following Equation.

$$Qe = mw.cp.\Delta Tw \qquad 2.4$$

Where:

Qe : Heat load to be emitted by the pipes.

mw: mass flow rate of water.

Cp: water specific heat that equal 4.18 kJ/kg.k

ΔTw: Water drop temperature

2.7.8 Selection of Pipe Diameter with Considering the Flow Velocity

The selection of pipe diameter depends upon the flow velocity since the inner surface of PEX pipe is quite smooth and scales do not form easily, the limitations to flow velocity for noise consideration is somehow less than that for metallic pipes. The maximum flow velocity is to be 1.2 m/s for residential building and can reach 2.4 m/s for industrial building[3], Flow velocity is given by the following Equation:

$$V_w = 4 \times \frac{\left(\frac{m_w}{\rho_w}\right)}{(\pi \times d_i^2)} \qquad 2.5$$

Where:

V_w : flow velocity (m/s) .

m_w : mass flow rate of water (kg/s) .

ρ_w : water density (kg/m^3) .

d_i : Inner diameter (m)

2.7.9 Calculate the Pressure Drop for the Longest Pipe Loop and the Pressure Drop Due to the Bending.

The pressure drop in the pipe per unit length is given by

$$\Delta p/\Delta L = f \times \rho \times \frac{V_w^{\ 2}}{2 \times d_i} \qquad 2.6$$

Where:

f: Friction coefficient.

ρ : Water density (kg/m^3).

V_w : Flow velocity(m/s).

d_i : Inner diameter (m).

The total pressure drop is then calculated by multiplying (Δp /L) by the total equivalent length of the pipe measured from the drawing directly or calculated from Equation (5-2) plus the length from manifolds to the zone for the longest loop.

The additional pressure drop due to pipe bending should be taken into consideration. It is given by the follow ing Equation:

$$\Delta PB = N \times K \times \rho \times \frac{V^2_{\ w}}{2} \qquad 2.7$$

Where:

N : Number of 90^o bends in the loop.

K : Loss coefficient from Table (E-1) APPINDIX(G) .

And U bend is considered as two 90^o bends.

The total pressure drop across the pipe loop is[5]

$$\Delta P = \Delta PB + \left(\frac{\Delta p}{\Delta L} \times L_{LOOP} \right) \qquad 2.8$$

Chapter Three

Heat Pumps Systems & Diesel Boilers

Chapter Three
Heat Pumps Systems & Diesel Boilers

3.1 Introduction

Recently many scientists & researchers have tried to solve the problem of the feasible use of energy. Engineers and scientists study modern ways to the most cost-effective and productive using of existing sources of energy, and also the possibility of using the maximum from natural renewable resources of energy. One of these ways is using heat pump for heating systems and hot water systems.

Now heat pumps are successfully used in many countries in the world. However, heat pumps are used generally in one family houses. It is known, the higher temperature of the low-temperature heat source , the more heat pump can transfer heat to a heating system.

Generally, use of heat pumps in heating system is reasonable when temperature parameters of heat transfer fluid are low. Temperature of water in under floor heating system is 50 – 35 degrees. This temperature interval is satisfying of required for heat pump efficiency. In this situation combine an under floor heating with a heat pump is the most simple solution.

Heat-pump water heaters, Almost all heat pumps work on the principle of the vapor compression cycle. Heating-only, space-heating heat pumps are manufactured in a variety of sizes ranging from 1 kW heating capacity for single room units, to 50−1000 kW for commercial/ institutional applications, and tens of MW for district heating plants. Most small to medium-sized capacity heat pumps in buildings are standardized factory-made units. Large heat pump installations usually are custom-made and are assembled at the site. In several countries water heating for swimming pools is provided by heat pumps. This is a growing market for heat pumps.

Heat sources include outdoor, exhaust and ventilation air, sea and lake water, sewage water, ground water, earth, industrial wastewater and process waste heat. Air-source and ground-coupled heat pumps dominate the market. For environmental reasons, many countries discourage the use of ground water from wells as a heat pump source (ground subsidence, higher-value uses for well water). In countries with cold climates such as in northern Europe, some heat pumps are used for heating only.

In countries with warmer climates, heat pumps serve hydronic systems with fan coils provide heat in the winter and cooling in the summer. Heat pumps with dual functions, such as heating water and cooling air simultaneously, are also available. In mature markets, such as Sweden, heat pumps have a significant market share as heating systems for new buildings and are entering into retrofit markets as well. In Europe, comfort heating dominates heat pump markets − mostly with hydronic systems using outside air or the ground. There is increasing use of heat pumps that recover a portion of exhaust heat in ventilation air to heat incoming air in balanced systems. This reduces the thermal load compared to having to heat the incoming air with primary fuel or electricity.

Heat pumps in Germany and Sweden provide up to 85% of the annual heating in some buildings. For these buildings, supplementary heat is required only on the coldest days. Heat pumps have up to a 95% share of heating systems in new buildings in Sweden. This is due to the initial development support and subsidies from the government that made the units reliable and popular, high electricity and gas prices, widespread use of hydronic heating systems, and rating as a ‘green’ heating system by consumers. Heat pumps for combined comfort heating and domestic hot-water heating are used in some European countries.

Most of the combined systems on the market alternate between space and water heating, but units simultaneously serving both uses are being introduced. The heat pumps for comfort heating have capacities up to 25 kW. Supply temperatures are (35−45°C) for comfort heat in new constructions and (55−65°C) for retrofits. Regulations in a number of European countries require domestic water heaters to produce supply temperatures of 60−65°C. Small capacity (10−30 kW) air-to-water heat pump chillers for residential and light commercial use in combination with fan-coil units are popular in China as well as Italy, Spain, and other southern-European countries. Hot water delivery temperatures are in the 45−55°C range. [4]

In the future, the market growth of small air-to-water heat pumps may be slowed in some markets by the growing popularity of variable-refrigerant-flow systems combined with multiple, indoor fan coil units connected to a refrigerant loop for direct refrigerant-to-air heat transfer. In Japan, heat pump chillers are mainly for commercial applications above 70 kW. Commercial size heat pump chillers of up to 700 or 1000 kW capacity are used for retrofit, replacing old chillers and boilers to vacate machine room space and eliminate cooling towers. Night-time electricity rates in Japan are only 25% of daytime rates. As a consequence, domestic hot-water heat pumps are a rapidly-growing market. They are operated only at night and the hot water is stored for daytime use. Germany and Austria have been installing dedicated domestic hot water (DHW) heat pumps for a number of years [1, 5].

3.2 Heat pump systems (Operation principle of heat pumps)

We can find quite a few definitions of the Heat Pump in literature, but importance of these is same – it is cooling machine where low-temperature environment's heat is delivered to high-temperature heat transfer fluid by means of using of energy on converting of machine's working medium.

The heat pump is a refrigerator but conversely. It contains an evaporator, volumetric compressor, condenser and expansion valve. Refrigerant which is used in system as working substance can start boiling by subzero temperature. The schematic diagram of a heat pump is shown in Figure 3.1:

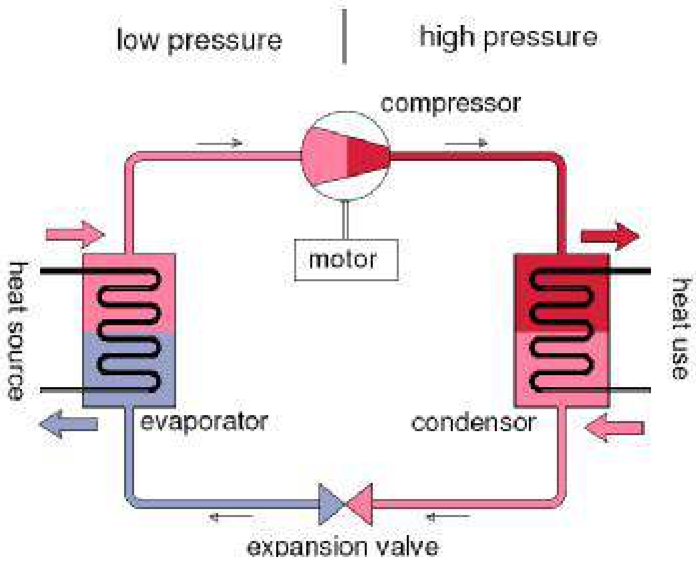

Figure (3.1): Schematic diagram of a compression heat pump.

It should be noted that advantage of heat pump in comparison with other source of heat is the heat pump transfers the energy, but does not produce it. The heat pump changes energy from low-temperature to high-temperature and vice versa.

1) The Refrigerant resides in vapor state with low pressure and temperature on exit from the evaporator.

2) The Refrigerant in vapor state enters compressor. The Refrigerant pressure is raised, the temperature is raised inside the compressor.

3) After that this hot Refrigerant in vapor state is cooled and condensed inside the condenser. As result, the Refrigerant passes into liquid state. During this condensing process the heat from the hot Refrigerant is released to water or air, which are used for heating purposes.

4) The Refrigerant turns into liquid state with high pressure on exit from the condenser. In this state the liquid get into a flow control device

which decompresses it quickly. During this part of the liquid is evaporating and passing into vapor state. Obtained vapor-liquid mixture enters evaporator. The Refrigerant gets heat from surrounding environment; during this the liquid is boiling inside the evaporator and turning into vapor state fully. Obtained superheated vapor exits from the evaporator.

5) The cycle will repeat.

In summary, the Refrigerant circulates over one cycle constantly and changes its phase state from liquid state to vapor state and vice versa.

The heat pump can work as heating or cooling machine, it change the direction of the Refrigerant transfer thought the evaporator and the condenser. The first case may be used in winter time for heating system, and the second case may be used in summer time for cooling system. The circulation system, which is working whole the year and generating both heat and cool in winter or summer seasons accordingly.

3.3 Boilers

3.3.1 Introduction:

A **boiler** is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and cheap medium for transferring heat to a process. When water is boiled into steam its volume increases about

1,600 times, producing a force that is almost as explosive as gunpowder. This causes the boiler to be extremely dangerous equipment that must be treated with utmost care. The process of heating a liquid until it reaches its gaseous state is called evaporation. Heat is transferred from one body to another by means of (1) radiation, which is the transfer of heat from a hot body to a cold body without a conveying medium, (2) convection, the transfer of heat by a conveying medium, such as air or water and (3) conduction, transfer of heat by actual physical contact, molecule to molecule[6].

3.3.2 Boiler Specification

The heating surface is any part of the boiler metal that has hot gases of combustion on one side and water on the other. Any part of the boiler metal that actually contributes to making steam is heating surface. The amount of heating surface of a boiler is expressed in square meters. The larger the heating surface a boiler has, the more efficient it becomes. The quantity of the steam produced is indicated in tons of water evaporated to steam per hour. Maximum continuous rating is the hourly evaporation that can be maintained for 24 hours. F & A means the amount of steam generated from water at 100 °C to saturated steam at 100 °C [6].

3.3.3 Boiler Systems & Operation

The boiler system comprises of: feed water system, steam system and fuel system. The **feed water system** provides water to the boiler and regulates it automatically to meet the steam demand. Various valves provide access for maintenance and repair. The **steam system** collects and controls the steam produced in the boiler. Steam is directed through a piping system to the point of use. Throughout the system, steam pressure is regulated using valves and checked with steam pressure gauges. The **fuel system** includes all equipment used to provide fuel to generate the necessary heat. The equipment required in the fuel system depends on the type of fuel used in the system. A typical boiler room schematic is shown in Figure 2.2 [6].

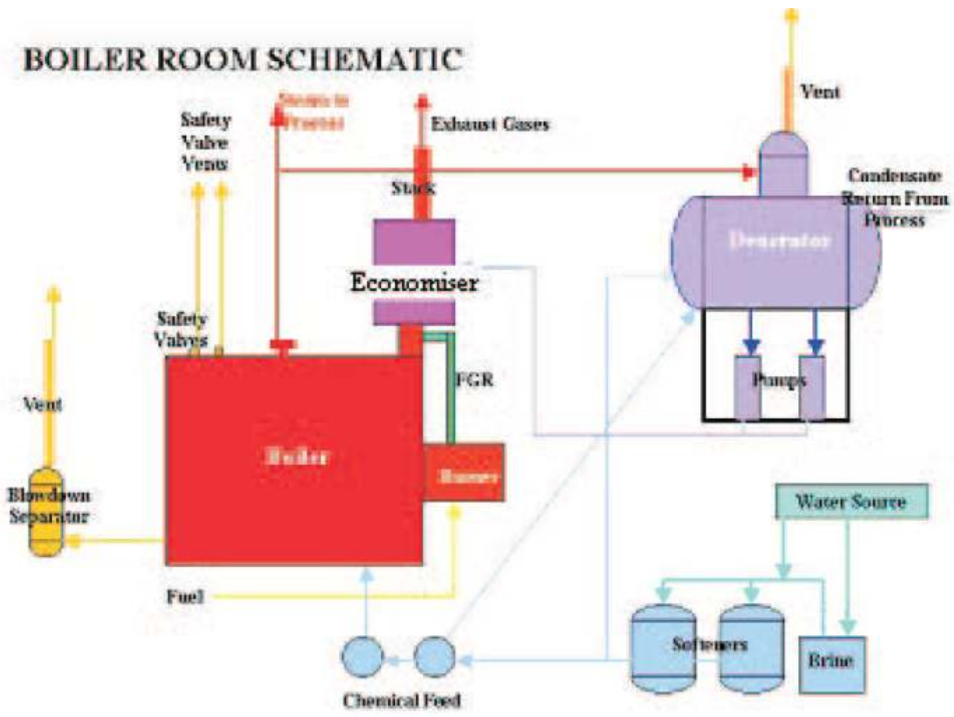

Figure (3.2): Boiler Room Schematic

The water supplied to the boiler that is converted into steam is called **feed water**. The two sources of feed water are: (1) **Condensate** or condensed steam returned from the processes and (2) **Makeup water** (treated raw water) which must come from outside the boiler room and plant processes. For higher boiler efficiencies, the feed water is preheated by economizer, using the waste heat in the flue gas [6].

3.3.4 Boiler Types and Classifications

There are virtually infinite numbers of boiler designs but generally they fit into these categories:

3.3.4.1 Fire tube

"Fire in tube" boilers; contain long steel tubes through which the hot gasses from a furnace pass and around which the water to be converted to steam circulates.

(Refer Figure 3.3). Fire tube boilers, typically have a lower initial cost, are more fuel efficient and easier to operate, but they are limited generally to capacities of 25 tons/h and pressures of 17.5 kg/cm^2.

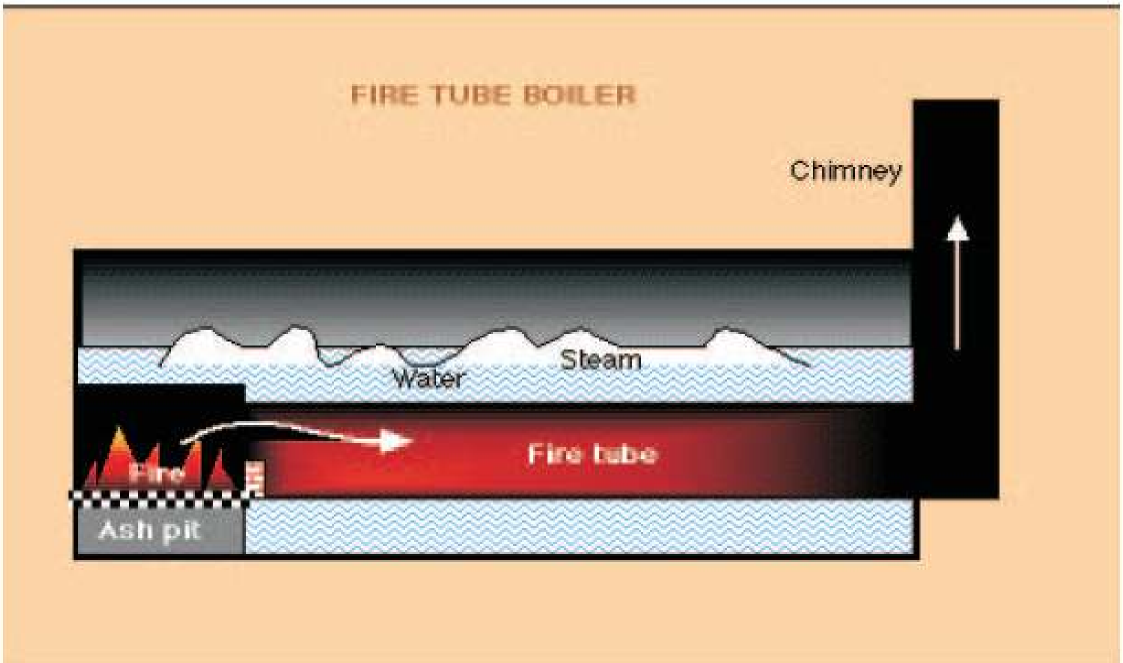

Figure (3.3): Fire Tube Boiler

3.3.4.2 Water tube

"Water in tube" boilers in which the conditions are reversed with the water passing through the tubes and the hot gasses passing outside the tubes (see figure 2.4). These boilers can be of single- or multiple-drum type. These boilers can be built to any steam capacities and pressures.

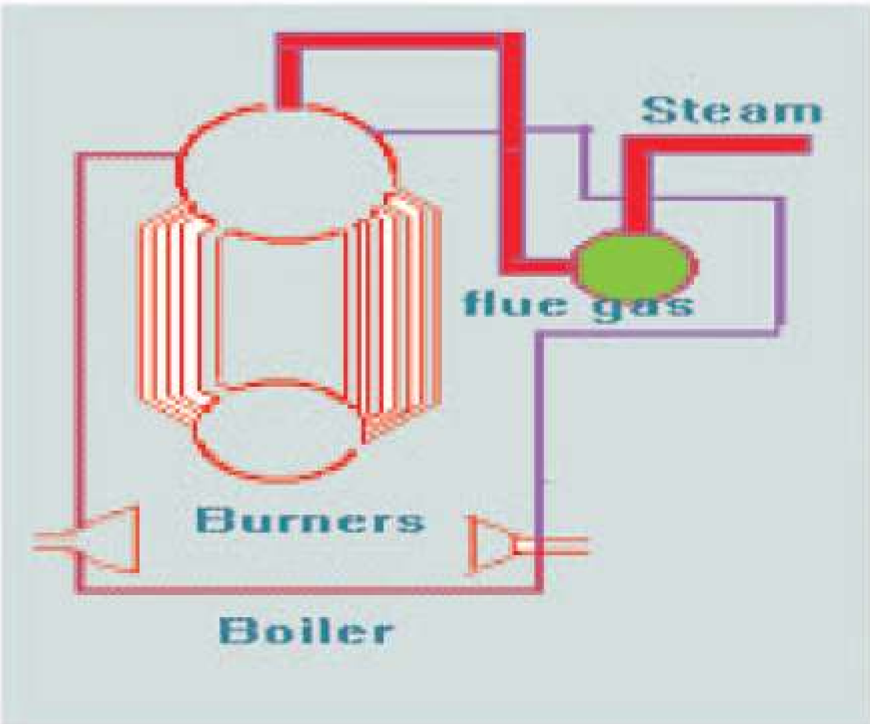

Figure (3.4): Water Tube Boiler

3.3.4.3 Packaged Boiler

The packaged boiler is so called because it comes as a complete package. Once delivered to site, it requires only the steam, water pipe work, fuel supply and electrical connections to be made for it to become operational. Package boilers are generally of shell type with fire tube design so as to achieve high heat transfer rates by both radiation and convection (Refer Figure 2.5).

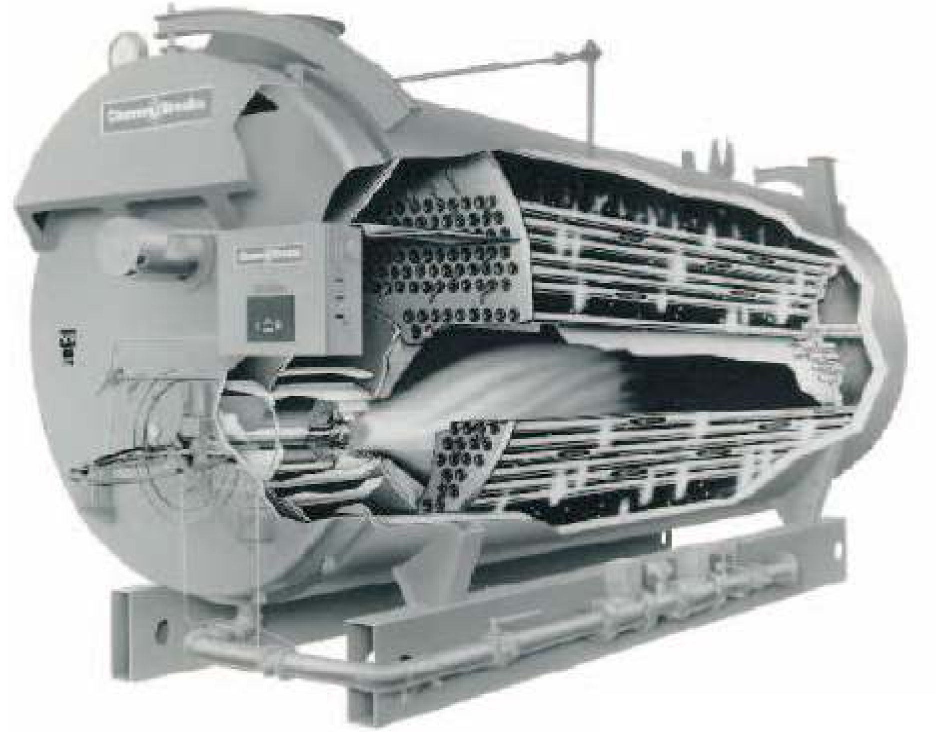

Figure (3.5): Packaged Boiler

3.3.4.3.1 The features of package boilers are

- Small combustion space and high heat release rate resulting in faster evaporation.
- Large number of small diameter tubes leading to good convective heat transfer.
- Forced or induced draft systems resulting in good combustion efficiency.
- Number of passes resulting in better overall heat transfer.
- Higher thermal efficiency levels compared with other boilers.

These boilers are classified based on the number of passes – the number of times the hot combustion gases pass through the boiler. The combustion chamber is taken, as the first pass after which there may be one, two or three sets of fire-tubes. The most common boiler of this class is a three-pass unit with two sets of fire-tubes and with the exhaust gases exiting through the rear of the boiler.

3.3.4.4 Stoker Fired Boiler

Stokers are classified according to the method of feeding fuel to the furnace and by the type of grate. The main classifications are:

1. Chain-grate or traveling-grate stoker
2. Spreader stoker

3.3.4.5 Chain-Grate or Traveling-Grate Stoker Boiler

Coal is fed onto one end of a moving steel chain grate. As grate moves along the length of the furnace, the coal burns before dropping off at the end as ash. Some degree of skill is required, particularly when setting up the grate, air dampers and baffles, to ensure clean combustion leaving minimum of unburnt carbon in the ash.

The coal-feed hopper runs along the entire coal-feed end of the furnace. Acoal grate is used to control the rate at which coal is fed into the furnace, and to control the thickness of the coal bed and speed of the grate. Coal must be uniform in size, as large lumps will not burn out completely by the time they reach the end of the grate. As the bed thickness decreases from coal feed end to rear end, different amounts of air are required- more quantity at coal-feed end and less at rear end (see Figure 3.6).

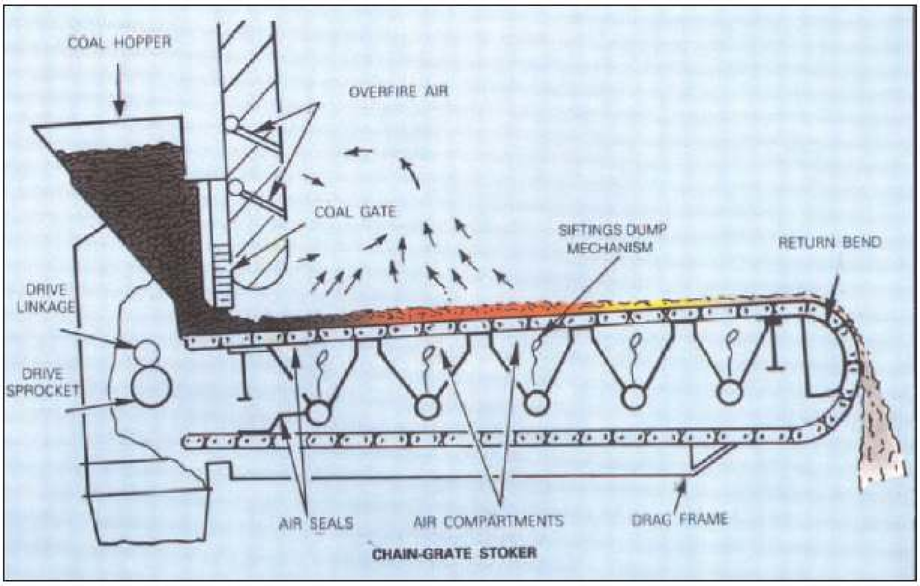

Figure (3.6) Chain Grate Stoker

3.3.4.6 Spreader Stoker Boiler

Spreader stokers (see figure 3.7) utilize a combination of suspension burning and grate burning. The coal is continually fed into the furnace above a burning bed of coal. The coal fines are burned in suspension; the larger particles fall to the grate, where they are burned in a thin, fast burning coal bed. This method of firing provides good flexibility to meet load fluctuations, since ignition is almost instantaneous when firing rate is increased. Hence, the spreader stoker is favored over other types of stokers in many industrial applications.

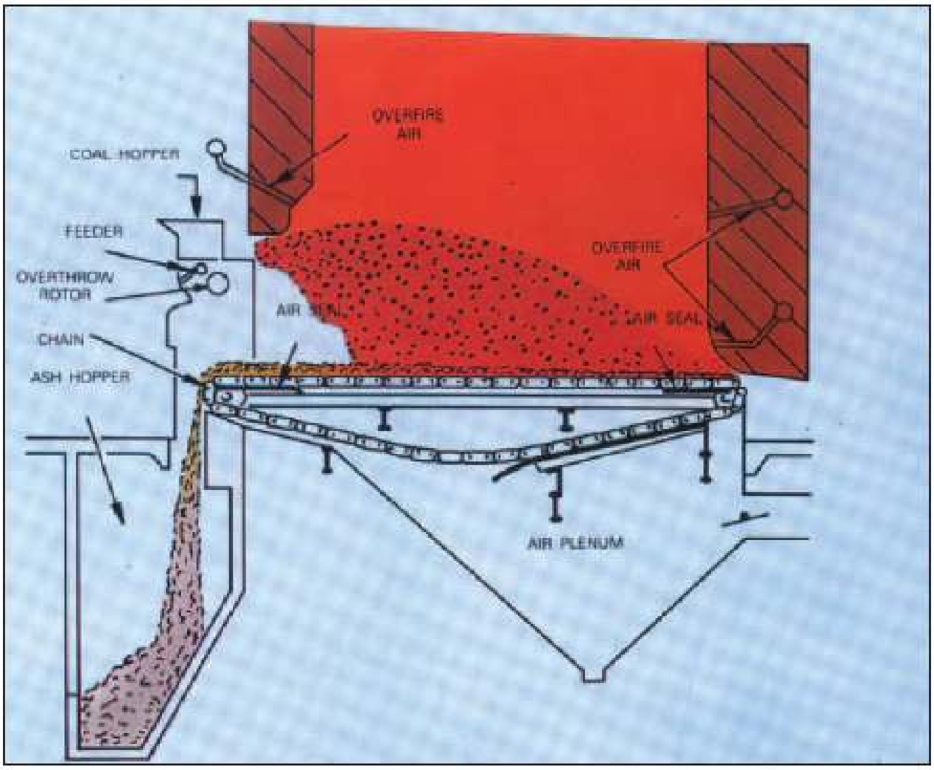

Figure (3.7): Spreader Stoker

3.3.4.7 Pulverized Fuel Boiler

Most coal-fired power station boilers use pulverized coal, and many of the larger industrial water-tube boilers also use this pulverized fuel. This technology is well developed, and there are thousands of units around the world, accounting for well over 90% of coal-fired capacity. The coal is ground (pulverized) to a fine powder, so that less than 2% is +300 micro meter (μm) and 70-75% is below 75 microns, for a bituminous coal. It should be noted that too fine a powder is wasteful of grinding mill power. On the other hand, too coarse a powder does not burn completely in the combustion chamber and results in higher un burnt losses. The pulverised coal is blown with part of the combustion air into the boiler plant through a series of burner nozzles. Secondary and tertiary air may also be added. Combustion takes place at temperatures from 1300-1700°C, depending largely on coal grade. Particle residence time in the boiler is typically 2 to 5 seconds, and the particles must be small enough for complete combustion to have taken place during this time. This system has many advantages such as ability to fire varying quality of coal, quick responses to changes in load, use of high pre-heat air temperatures etc. One of the most popular systems for firing pulverized coal is the tangential firing using four burners corner to corner to create a fireball at the center of the furnace (see Figure 3.8).

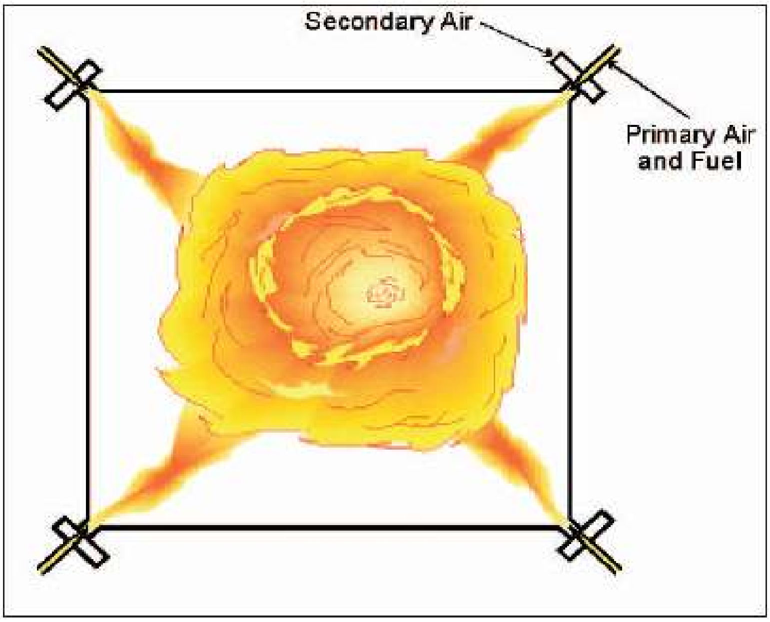

Figure (3.8): Tangential Firing

3.3.4.8 FBC (Fluidized Bed Combustion) Boiler

When an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on a fine mesh, the particles are undisturbed at low velocity. As air velocity is gradually increased, a stage is reached when the individual particles are suspended in the air stream. Further, increase in velocity gives rise to bubble formation, vigorous turbulence and rapid mixing and the bed is said to be fluidized. If the sand in a fluidized state is heated to the ignition temperature of the coal and the coal is injected continuously in to the bed, the coal will burn rapidly, and the bed attains a uniform temperature due to effective mixing. Proper air distribution is vital for maintaining uniform fluidization across the bed.). Ash is disposed by dry and wet ash disposal systems.

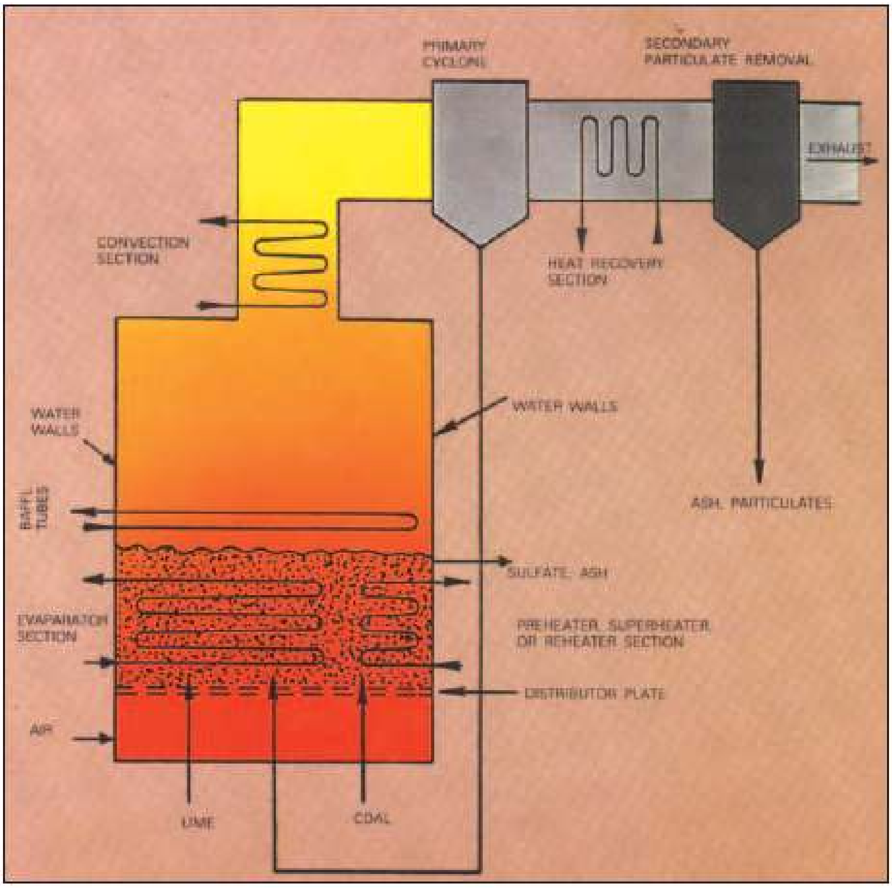

Figure (3.9): Fluidized Bed Combustion

Fluidized bed combustion has significant advantages over conventional firing systems and offers multiple benefits namely fuel flexibility, reduced emission of noxious pollutants such as SOx and NOx, compact boiler design and higher combustion efficiency (see figure 3.9) [6].

Chapter Four

Mathematical Model & Calculations

Chapter Four
Mathematical Model & Calculations

4.1 Introduction

Low-temperature heat emission systems such as under floor heating are well suited for combination with heat pump systems. The large heat exchange area allows for low supply water temperatures, while the high thermal capacity allows to reduce thermal power peaks. Both have a positive impact on the coefficient of performance, (COP) of the heat pump. The thermal inertia makes it however difficult to guarantee thermal comfort. First, the heat emission system cannot react on fast changing heat loads, which may cause large swings in the operative temperature. Second, due to the time lag between heat production and heat emission, the installation must anticipate on the future building loads. Room thermostat control is therefore not suited for this kind of slow reacting system. Current practice is to control the supply or return water temperature based on a weather dependent heating curve. The latter relates the set point water temperature to the daily mean ambient temperature, based on a static building model. To account for the thermal inertia of the floor heating, additionally start/stop-algorithms are needed. Careful tuning of the parameters of these rules based set of Low-temperature heat emission systems such as floor heating are well suited for combination with heat pump systems. The high thermal capacity allows to reduce thermal power peaks. Both have a positive impact on the coefficient of performance (COP) of the heat pump [1].

The thermal inertia makes it however difficult to guarantee thermal comfort. First, the heat emission system cannot react on fast changing heat loads, which may cause large swings in the operative temperature. Second, due to the time lag between heat production and heat emission, the installation must anticipate on the future building loads. Room thermostat control is therefore not suited for this kind of slow reacting system. Current practice is to control the supply or return water temperature based on a weather dependent heating curve. The latter relates the set point water temperature to the daily mean ambient temperature, based on a static building model. To account for the thermal inertia of the floor heating, additionally start/stop-algorithms are needed. Careful tuning of the parameters of these rule based control is affected by solving a convex approximation of the optimization problem based on a simplified heat pump model, instead of a nonlinear problem incorporating a detailed heat pump model [1].

4.2 Mathematical Modeling

The present study aims at comparing the performance of a modulating air-to-water heat pump connected to a floor heating system with a diesel boiler system in a residential building. The level of detail of the heat pump model included in COP formulation, is varied. The most detailed model incorporates the dependency of the heat pump performance on the source temperature, the supply temperature and the compressor frequency, while the most simple one assumes a constant COP. The performance at the heat pump level is assessed using performance maps from the heat pump manufacturer. Additionally, the energy saving potential of optimal control for the investigated case is quantified in terms of electricity consumption. To this end, the optimization-based control strategies are compared to a conventional heating curve control strategy. [11]

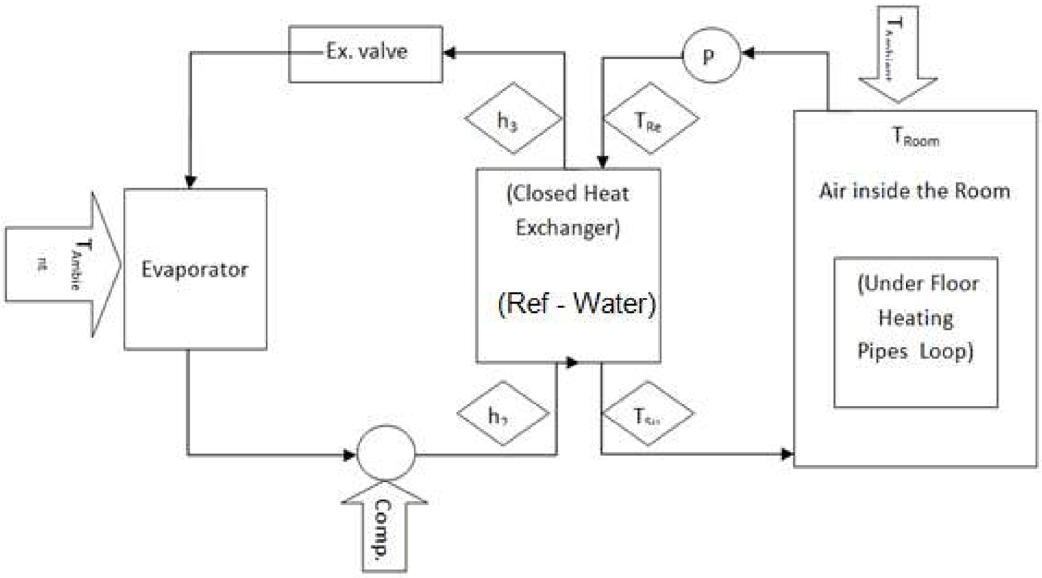

Figure (4.1): Schematic Diagram for Under Floor Heating System Utilizing Heat Pump System as a heat source.

(Gas – Water) Heat Exchanger

When water pass through the Closed Heat Exchanger, heat transferred from the refrigerant to water assuming (heat exchanger efficiency , $\zeta_{H/E}$ = 100%) , then directly pumped to the Under Floor Heating Loop, Energy Balance for the HE:

$$Q\ (from\ refrigerant) = Qwater\ (from\ Heat\ Exchanger)$$
$$= Q\ (air\ in\ room)$$

$$Q\ (from\ refrigerant) = \dot{m}w.Cp.(Tw,supply - Tw,return) \qquad (4.1)$$

(Floor Area – Room Air)

Hot water comes out from the closed Heat Exchanger to the under floor heating loop, then heat normally transferred to the air inside the room assuming that the ground is well insulated, amount of heat loss through ground will be ignored , the energy balance:

$$\dot{m_w}\ Cp.(Tw,supply - Tw,return)$$
$$= U.A\ (overall)\ .(Troom - TAmbient)$$

4.2.1 Heating Load inside the Room Based on Heat Pump (Source)

$$\boldsymbol{Q = U.A.(Troom - Tambient)} \qquad (4.2)$$

$$\boldsymbol{Q} = \boldsymbol{Q}walls + \boldsymbol{Q}ceilings + \boldsymbol{Q}doors + \boldsymbol{Q}windows + \boldsymbol{Q}infiltration$$

The total Heating Load can be calculated by assuming:

T_{Room} = 21 ˚C.

$T_{Ambient}$ = 7 ˚C,

$T_{Unheated\ space}$ = 12 ˚C.

$U_{Internal\ wall}$ = 2.7 (w/m^2 .k)

$U_{External\ wall}$ = 1.7 (w/m^2 .k)

U_{Window} = 3.2 (w/m^2 .k)

L = 4 m (Room Length)

W = 4 m (Room Width).

H = 3 m (Room Height).

T_{room} = 24 C.

$U_{Doors} = 2.26\ (w/m^2.k)$

$U_{Cieling} = 0.88\ (w/m^2.k)$

L = 4 m (Room Length)

W = 4 m (Room Width).

H = 3 m (Room Height).

Window area = 1 * 1 = 1 m^2.

Door Area = 2 * 1 = 2 m^2.

$Q_{Heating\ Load} = U.A.(T_{Room} - T_{Ambient})$.

$A_{Internal} = A_{Walls} - A_{Door} = 2 * 4 * 3 - 2 = 22\ m^2$.

$A_{External} = A_{Walls} - A_{Window} = 2 * 4 * 3 - 1 = 23\ m^2$.

$$\dot{V}_{infiltration} = ACH\ (Air\ Change\ per\ Hour) * V\ (Volume)$$

Then,

$$Q(Heating\ Load) = Q(External\ walls) + Q(Internal\ walls) + Q(ceiling) + Qdoor + Qwidow + Qinf. \quad (4.3)$$

$$Q = [U(external)A(external) + U(ceiling)A(ceiling) + U(window)A(window)](Troom - TAmbient)$$

$$+[U(internal)A(internal) + U(door)A(door)](Troom - Tunheated) + \rho\,\dot{V}Cp(T\ room - T\ ambient)$$

$Q = [(1.2)(23) + (0.88)(16) + (3.2)(1)](24 - 7) + [\,(2.7)(22) + (2.26)(2)](24 - 12)$+[0.98*0.1*1*(21-7)]

$$Q = 762.96 + 767.04 = 1530.37\, w$$

$$Q = 1530.37w/16\, m^2 \;= 95.71\, w/m^2$$

The heating load then can be calculated using the same procedure as discussed in Appendix E, for the apartment total area (78.3) m^2, the result for the above mentioned inputs is : Q_{HL} = 6.11 kW. Then, The mass flow rate of water inside the pipes loop must be calculated by dividing the Heating Load by the Temperature difference between the surface = 28 ˚C & the Hot water storage tank = 40 ˚C.

$$\dot{m} \;= \frac{\text{Q (Heating Load)kw}}{\text{Cp}\left(\frac{\text{kJ}}{\text{kg.C}}\right)\text{.Temperature Difference }(^{o}\text{C})} \tag{4.4}$$

$$\dot{m} \;= \frac{1.53}{(4.18)\,.\,(40 - 28)\;(^{o}\text{C})}$$

$$\dot{m} \;= 0.0305\;\frac{kg}{s}$$

After that, the COP must be calculated in order to calculate the Power input to the HP unit that operate under floor heating system, Using the Equation [13]

Table (4.1) Constants Values used in the COP Equation. [7]

c_0	8.24
c_1	1.58×10^{-1}
c_2	-1.95×10^{-1}
c_3	1.01×10^{-3}
c_4	1.48×10^{-3}
c_5	-2.33×10^{-3}
d_0	9.35
d_1	3.19×10^{-1}
d_2	-6.13×10^{-2}
d_3	4.44×10^{-3}
d_4	2.45×10^{-3}

$$COP = c_0 + c_1 T_{amb} + c_2 T_{w,s} + c_3 T_{amb}^2 + c_4 T_{w,s}^2 + c_5 T_{amb} T_{w,s} \tag{4.5}$$

$$\text{COP} = 8.24 + 0.158 * 7 + -0.195 * 42 + \left(\frac{1.01}{1000}\right) * 7 * 7 + \left(\frac{1.48}{1000}\right) * 42^2 + -\left(\frac{2.33}{1000}\right) * 7 * 42$$

$$= 3.13$$

Then, the input power is:

$$P = \frac{\text{Q (Heating Load)kW}}{\text{COP}} \tag{4.6}$$

$$P = \frac{1.53}{3.13} = 0.49 \text{ kW}$$

The Energy Consumption can be calculated during 12 hours of operation, (assumed continuous operation during 12 hours/day only) :

$$E = P\ (kW) * T(Hours) \tag{4.7}$$

$$E = 0.49 * 12 = 5.88\ kWh$$

Then, we have to calculate the cost of energy consumption according to the cost of 1kwh of electrical energy:

$$Cost = E\ (kWh) * Currency(NIS/kwh) \qquad (4.8)$$

$$Cost = 5.88 * 0.65 = 3.81\ NIS/day$$

4.3 Heating Load inside the Room Based on Diesel Boiler (Source)

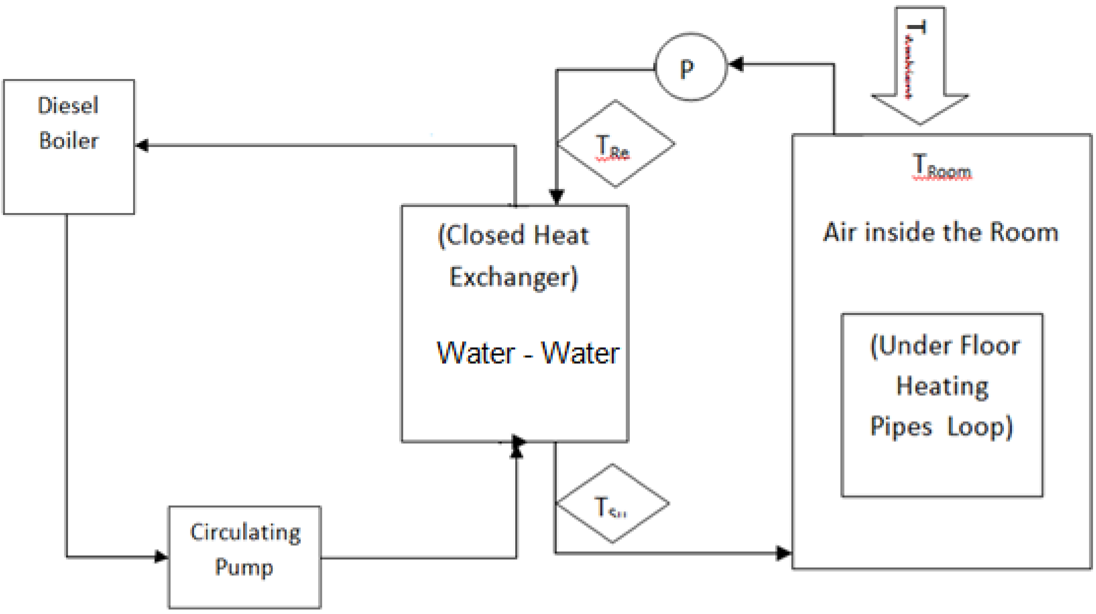

Figure (4.2): Schematic Diagram for Under Floor Heating System Utilizing Diesel water Boiler System as a heat source.

The mass flow rate of diesel can be calculated using equation (4.4)

$$\dot{m}\ (\frac{\text{kg}}{\text{s}}) = \frac{\text{Q (Heating Load)kw}}{(\zeta)\text{Boiler Efficiency} * \text{Heating Value}(\frac{\text{kJ}}{\text{kg}})}$$

$$\dot{m} = \frac{1.53}{0.8 * 44800}$$

$$\dot{m} = 4*10^{-5}\ (\text{kg/s})$$

The amount of diesel consumption per day can be calculated using equation (4.9), assuming 12 hors/day continuous operation.

$$\dot{m}\ (\frac{\text{L}}{\text{Day}}) = \frac{\text{Mass Flow Rate}\left(\frac{\text{kg}}{\text{s}}\right)*3600*12}{\text{Conversion Factor to litre of diesel}} \qquad (4.9)$$

$$\dot{m} = \frac{0.00004 * 3600 * 12}{0.835}$$

$$\dot{m} = 2.208\ (\frac{\mathrm{L}}{\mathrm{Day}})$$

Then we can estimate the cost of energy consumption,

$$Cost\ (NIS) = \text{Diesel Consumption}\ (\frac{\mathrm{L}}{\mathrm{Day}}) * \text{cost}\ (\frac{\mathrm{NIS}}{\mathrm{L}})$$

$$Cost\ (NIS) = 2.208 * 7.2$$

$$Cost\ (NIS) = 15.89\ \mathrm{NIS}$$

4.4 Comparative Analysis for both Systems

The up mentioned calculations for both Systems are made to have more details about the operating parameters for both systems when using in loops of under floor heating method, so both systems must be compared from an engineering & economic points of view to clear image for selection from both to use, in this way, these information gained to simplify the procedure & criteria of selection.

Table (4.2) The Relation Between Heating Load Inside the Room & Ambient Temperature in Hebron During January – 2011.

Jan.2011	T	Q (Heating Load)
Day No.	Min.	kW
1	7	1.530
2	7	1.530
3	7.6	1.503
4	7.8	1.494
5	6	1.575
6	7	1.530
7	6.6	1.548
8	5	1.620
9	5	1.620
10	5.5	1.597
11	6	1.575
12	6	1.575
13	5.6	1.593
14	5.8	1.584
15	4	1.665
16	4.5	1.642
17	7	1.530
18	7.8	1.494
19	4	1.665
20	5.5	1.597
21	5	1.620
22	5.6	1.593
23	7	1.530
24	7.5	1.508
25	7	1.530
26	6.4	1.557
27	7.5	1.508
28	7	1.530
29	9	1.440
30	8	1.485
31	5	1.620

The relation between Heating Load (Q_{HL}) & $T_{Ambient}$, on January 2011 as in Tables in Appendix (C).

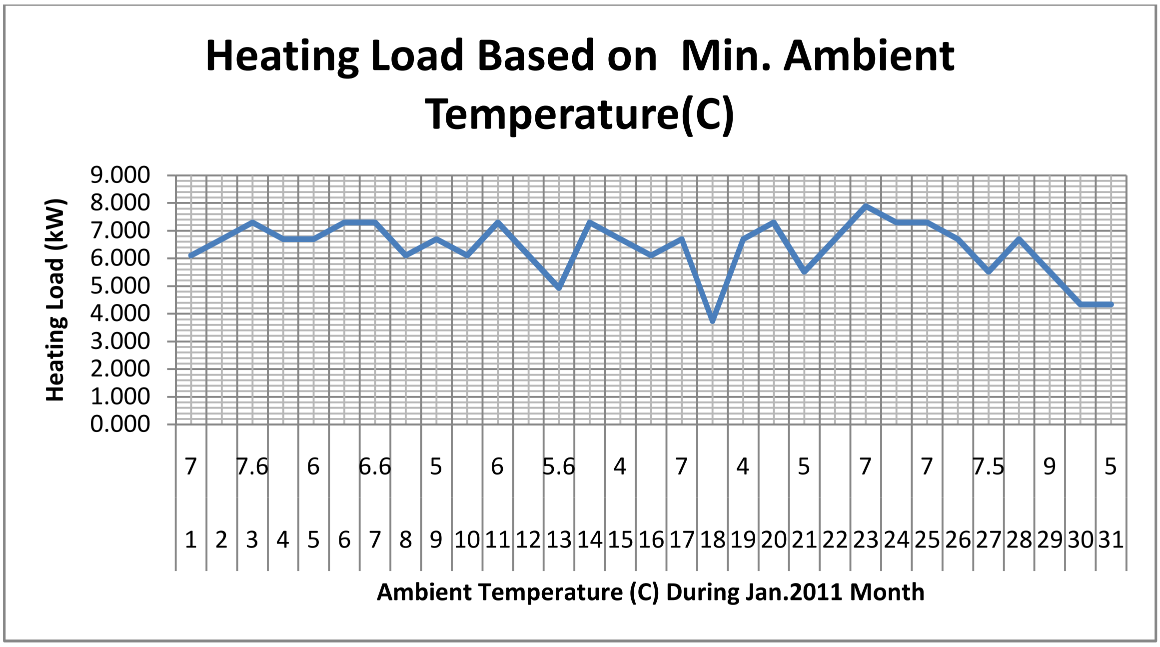

Figure (4.3) : The relation Between Heating Load inside the room & Ambient Temperature in January – 2011.

The comparative study between the minimum ambient temperature & the heating load inside the room clarifies that, the load is normally increase according the decrease of minimum ambient temperature due to the excess work to be done on the system to raise it to the stability conditions i.e (T = 24 °C) inside the room. As listed in table (4.2) for January – 2011, the remaining tables for other winter months are listed in Appendix C.

The comparative study between the minimum ambient temperature & the Coefficient of Performance for the Electric Heat Pump that is sufficient to the heating load inside the room, the COP is normally decreasing according the decrease of minimum ambient temperature. As listed in table (4.3) for January – 2011, the remaining tables for other winter months are listed in Appendix C.

Table (4.3) The relation between COP_{HP} & $T_{Ambient}$.

Jan.2011 Day No.	T Min.	COP Based on eq. 4.2
1	7	3.131
2	7	3.131
3	7.6	3.176
4	7.8	3.191
5	6	3.058
6	7	3.131
7	6.6	3.102
8	5	2.987
9	5	2.987
10	5.5	3.022
11	6	3.058
12	6	3.058
13	5.6	3.029
14	5.8	3.044
15	4	2.917
16	4.5	2.952
17	7	3.131
18	7.8	3.191
19	4	2.917
20	5.5	3.022
21	5	2.987
22	5.6	3.029
23	7	3.131
24	7.5	3.169
25	7	3.131
26	6.4	3.087
27	7.5	3.169
28	7	3.131
29	9	3.284
30	8	3.206
31	5	2.987

The relation between the Coefficient of Performance (COP_{HP}) & $T_{Ambient}$, on January 2011 from Appendix (C).

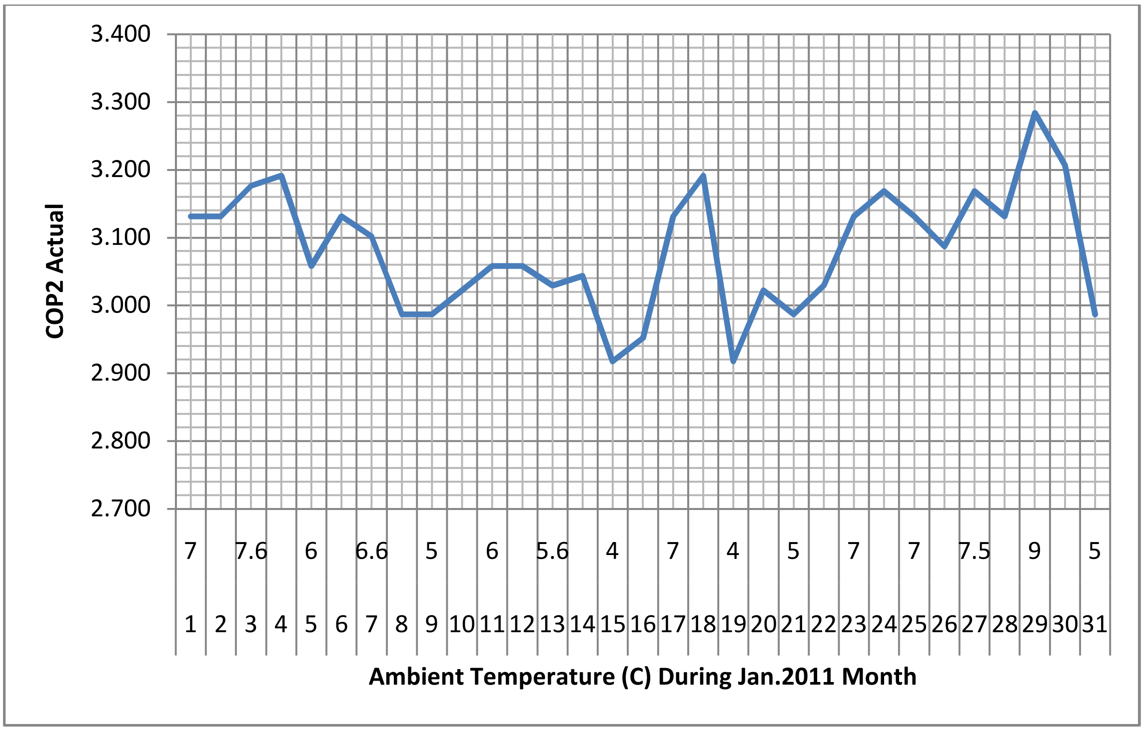

Figure (4.4) : The relation between COP_{HP} & $T_{Ambient}$.

The comparative study between the minimum ambient temperature & the Electrical Energy Input to the Heat Pump that is suitable to the heating load inside the room, table (4.4) clarify that the amount of electrical energy have to be consumed is increasing due the decreasing in the ambient temperature because we need more heat energy to be added to the conditioned space to keep the same conditions. As listed in table (4.4) for January – 2011, the remaining tables for other winter months are listed in Appendix C.

Table (4.4), from calculated tables in Appendix E1,E2 The Relation between the Input Energy to the HP & $T_{Ambient}$.

Jan.2011	T	Electrical Energy input to HP
Day No.	**Min.**	**(kWh)/day**
1	7	5.864
2	7	5.864
3	7.6	5.679
4	7.8	5.618
5	6	6.180
6	7	5.864
7	6.6	5.989
8	5	6.508
9	5	6.508
10	5.5	6.343
11	6	6.180
12	6	6.180
13	5.6	6.310
14	5.8	6.245
15	4	6.847
16	4.5	6.676
17	7	5.864
18	7.8	5.618
19	4	6.847
20	5.5	6.343
21	5	6.508
22	5.6	6.310
23	7	5.864
24	7.5	5.709
25	7	5.864
26	6.4	6.052
27	7.5	5.709
28	7	5.864
29	9	5.263
30	8	5.558
31	5	6.508

The relation between the Input Power to the HP & $T_{Ambient}$, on January 2011 from Appendix (C).

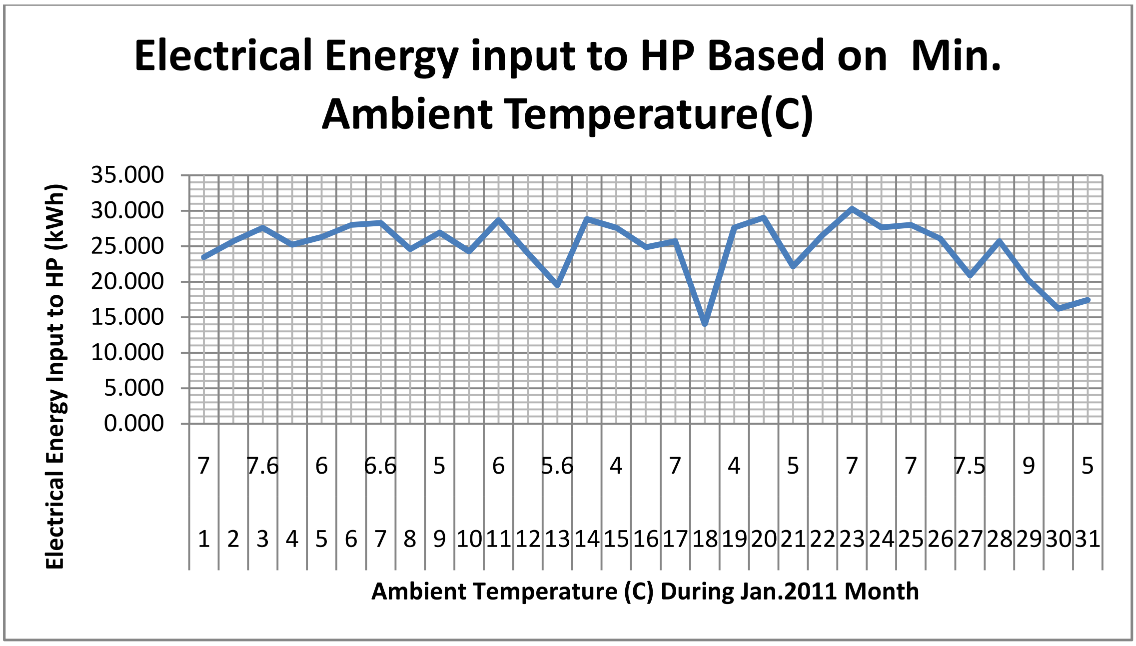

Figure (4.5) : The Relation between the Input Energy to the HP & $T_{Ambient}$.

The amount of fuel that consumed to be burned for heating is also increased according to the decrease in the minimum ambient temperature, for the up mentioned reasons, i.e. an excess amount of heat have to be added to the system using the diesel boiler to sustain the desired heating conditions.

Table (4.5), calculated tables in Appendix E3,E4 The Relation between the Amount of Diesel input to the Boiler & $T_{Ambient}$

Jan.2011	$T_{Min}(^oC)$	Fuel Flow Rate (kg/s)
Day No.		mf=QHL/(ζ***Heating Value)**
1	7	4.26897E-05
2	7	4.26897E-05
3	7.6	4.19384E-05
4	7.8	4.16879E-05
5	6	4.3942E-05
6	7	4.26897E-05
7	6.6	4.31906E-05
8	5	4.51942E-05
9	5	4.51942E-05
10	5.5	4.45681E-05
11	6	4.3942E-05
12	6	4.3942E-05
13	5.6	4.44429E-05
14	5.8	4.41924E-05
15	4	4.64464E-05
16	4.5	4.58203E-05
17	7	4.26897E-05
18	7.8	4.16879E-05
19	4	4.64464E-05
20	5.5	4.45681E-05
21	5	4.51942E-05
22	5.6	4.44429E-05
23	7	4.26897E-05
24	7.5	4.20636E-05
25	7	4.26897E-05
26	6.4	4.34411E-05
27	7.5	4.20636E-05
28	7	4.26897E-05
29	9	4.01853E-05
30	8	4.14375E-05
31	5	4.51942E-05

The relation between the amounts of Diesel consumption with the Heating Load:

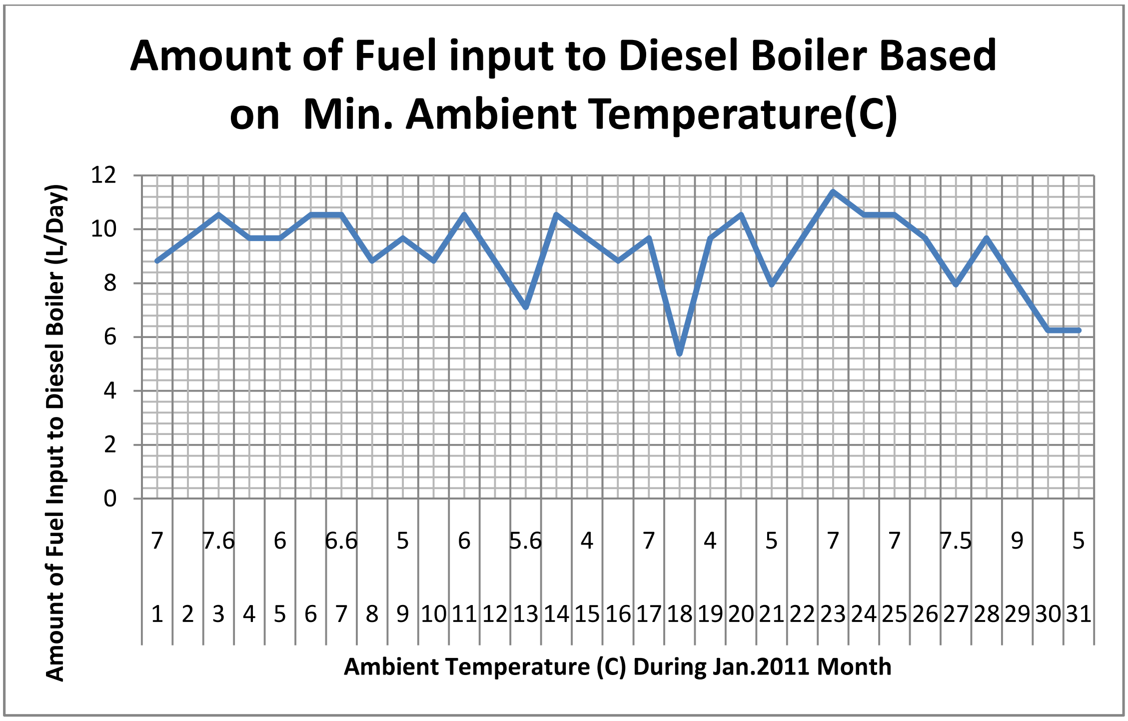

Figure (4.6) : The Relation between the Amount of Diesel input to the Boiler & $T_{Ambient}$.

4.5 Estimating Electrical Energy & Fuel Consumption for both systems using DD (Degree Days Method)

The calculation of energy requirements or fuel consumption for heating and cooling air conditioning systems for either short term or long term operation is difficult to perform. Records of energy or fuel consumption of past operating experience can provide reliable and accurate estimates. However, a simple procedure that uses the annual degree-day method can be applied to estimate the energy or fuel consumption for heating and cooling systems under typical winter and summer conditions. This procedure is only applied to residential and small commercial buildings[13]

The Degree-Day Method

The degree-day method is a simple method for estimating fuel consumption or electrical energy for a residential building if the efficiency of the air conditioning equipment is constant. The degree-day is a term used to help indicate the theoretical heating or cooling loads needed a given day, month or season of the year. This method is based on the assumption that, on long term bases, solar heat gain rate and internal heat gain rate due to occupants, lights, equipment and appliances of a given residential building during winter season are equal to the total heat loss of the building when the mean daily outdoor air temperature is equal to the balance point temperature of the building. The balance point temperature of the building is defined as that value of the average outdoor temperature at which, for a specified value of the inside temperature, the total heat loss rate from the building is equal to the heat gain rates from sun, occupants, lights, equipment and appliances. Its value is estimated as 18.3 ^{o}C for winter heating. Heating degree-days for a balance point temperature value of 18.3 ^{o}C. today, the use of T_{bal} = 18.3^{o}C will overestimate the fuel consumption due to improved building construction , as well as , increased internal heat gain rates in recent years . The error inherent in using the base temperature of 18.3c in calculating the degree-day values is adjusted by using an empirical factor c d . However, the best way is to use the variable base degree-day approach instead of the arbitrary base temperature of 18.3c. The variable base degree-day method counts the degree-day based on actual balance point temperature. [13] ASHRAE Hand book of Fundamentals, 2001 lists the degree-days for several base temperatures for various locations in the world [13].

The heating degree-days DD_h , based on base temperature of 18.3 ^oC for a given month are obtained from the following relation:

$$DD_H = (18.3- T_{avg})^+ * N \qquad (4.10)$$

Where T_{avg} is the monthly mean daily outside air temperature. N is the number of days of the given month. On the other hand, degree days, DD_H , for the heating season are calculated as follows:

$$DD_H = \sum_{Days}^{N}(18.3 - T\ avg)$$

Where the assumption of Eq (4.10) is extended over all days of the heating season. The fuel consumption for heating season is proportional to the difference between the mean daily outdoor air temperature and 18.3 C. i.e. proportional to $\sum_{Days}^{N}(18.3 - T\ avg)$.

The theoretical seasonal or annual energy requirements of a conventional heating system $Q_{H,\ theor}$, in units of KJ, using the degree-day method, is calculated as follows:

$$Q_{H,\ theor} = \frac{QH*3600*24*DD\ H}{Ti-T0}\ Cd \qquad (4.11)$$

Where Q_H is the design or the calculated heating load of the space in units of kW, which includes the infiltration load, DD_H is the number of the heating Degree Days for the required time period (one month or heating season period). The factor C_d is an empirical coefficient whose value depends on the value of the balance point temperature, and on the value of DD_H. the mass of the fuel M_{fuel}, consumed during a given period of time (one month or heating season period) during winter operation can be estimated from the following relation by using the degree-day method:

$$M_{Fuel} = \frac{Q\ H*3600*24*DD\ H}{(Ti-T0)*C.V}\left(\frac{Cd}{\zeta}\right) = \left(\frac{QH,theor}{CV*\zeta}\right) \qquad (4.12)$$

$$\left(\frac{\text{Mass of Fuel (kg)}}{Density\ of\ Fuel(\rho)}\right)$$

Where:

C.V : is the calorific or heating value of the fuel used in units of kJ/kg.

ζ : is the average efficiency of the heating system.

The value range of the efficiency for gas fired furnaces is 85% to 98%. On the, the value of the efficiency for liquid fuel furnaces is 75% to 90%. For electrical heating systems, the value of the efficiency is equal to 1.

C_d : an empirical correction factor for heating effect versus degree-day value whose value depends on the value of balance point temperature, and on the value of DD_H. its value equals to 0.77 if the balance point temperature is arbitrary assumed 18.3 ^{o}C. the value of C_d is 1 if the heating degree-day DD_H, are based on actual value of the balancing temperature. Typical calorific value for diesel fuel ranges from 39000 to 43000 kJ/kg, depending on the sulfur and nitrogen content of the diesel fuel. On the other hand, the calorific value of natural gas (specific gravity = 0.6) and manufactured gas is 38400 and 20500 kJ/m^3. [13]

Table (4-6) clarify the calculations of the Diesel Boiler consumption based on the DD_H Method during 2011 & 2012 respectively.

Average Outside Temp. during winter.(C)	(6.3+6.5+8.4+6.9)/4	7.0
Average Load for Space during winter (kW)	(6.4+6.1+6.4+6.3)/4	6.3
Theorotical Load (Q Theo.) (kJ/Season)= $\frac{QH * 3600 * 24 * DD\ H}{Ti - T0}\ Cd$	(6.3*3600*24*1056.72*0.77)/(21-7)	31635660.67
Mass of Fuel Consumed (kg/season)= $\left(\frac{QH, theor}{CV * \zeta}\right)$	31635661/(39000*0.8)	1013.96
Volume of the Diesel Tank (m3/season)= $\left(\frac{\text{Mass of Fuel (kg)}}{Density\ of\ Fuel(\rho)}\right)$	1013.96/850	1.193

Average Outside Temp. during winter.(C)	(5.52+4.6+12.9+7.79)/4	7.70
Average Load for Space during winter (kW)	(7.5+7.7+5.23+6.76)/4	6.80
Theorotical Load (Q Theo.) (kJ/Season)= $\frac{QH * 3600 * 24 * DD\ H}{Ti - T0}\ Cd$	(6.80*3600*24*741.88*0.77)/(21-7.7)	25234540.6
Mass of Fuel Consumed (kg/season)= $\left(\frac{QH, theor}{CV * \zeta}\right)$	25234540.6/(39000*0.8)	808.80
Volume of the Diesel Tank (m3/season)= $\left(\frac{\text{Mass of Fuel (kg)}}{Density\ of\ Fuel(\rho)}\right)$	808.80/850	0.95

Chapter Five

Economic & Environmental Impact Analysis of a Heat Pump versus Diesel Boiler

Chapter Five
Economic Analysis

5.1 Introduction

The need for engineering economy is primarily motivated by the work that engineers do in performing analysis, synthesizing, and coming to a conclusion as they work on projects of all scales. Thus, engineering economy is at the heart of making decisions. These decisions involve the fundamental elements of cash flows of money, time, and interest rates. This chapter introduces the basic concepts and terminology necessary for an engineer to combine these three essential elements in organized, mathematically correct ways to solve problems that will lead to better decisions. [14]

In order to apply economic analysis techniques, it is necessary to understand the basic terminology and fundamental concepts that form the foundation for engineering economy studies. An alternative is a stand-alone solution for a given situation. Selecting among different alternatives is an everyday task for all humans, involving engineers. To be more specific, in engineering practice, there are always several ways of accomplishing a given task, and it is necessary to be able to compare them in a rational manner so that the most economical alternative can be selected. The alternatives in engineering considerations usually involve such items as purchase cost (first cost), anticipated useful life, yearly costs of maintaining assets (annual maintenance and operating costs), anticipated resale value (salvage value), and the interest rate. After determining the parameters and all the relevant estimates have been collected, an engineering economy analysis can be conducted to determine which is best from an economic point of view.

Interest is the manifestation of the time value of money, and it essentially represents "rent" paid for use of the money. Computationally, interest is the difference between an ending amount of money and the beginning amount. If the difference is zero or negative, there is no interest . There are always two perspectives to an amount of interest—interest paid and interest earned. Interest is paid when a person or organization borrows money (obtains a loan) and repays a larger amount, while interest is earned when a person or organization saves, invests, or lends money and obtains a return of a larger amount. The computations and numerical values are essentially the same for both perspectives, but they are interpreted differently. Interest paid or earned is determined by using the relation (5.1).

$$\boldsymbol{Interest = End\ amount - Original\ amount} \qquad (5.1)$$

However, when interest over a specific time unit is expressed as a percentage of the original amount (principal), the result is called the interest rate or rate of return (ROR). **(5.2)**

$$\text{Interest rate or rate of return} = \frac{\text{interest accrued per time unit}}{\text{original amount}} * 100\%$$

(5.2)

The time unit of the interest rate is called the interest period. By far the most common interest period used to state an interest rate is 1 year.

Shorter time periods can be used, such as, 1% per month. Thus, the interest period of the interest rate should always be included. If only the rate is stated, for example, 8.5%, a 1-year interest period is assumed. The term return on investment (ROI) is used equivalently with ROR in different industries and settings, especially where large capital funds are committed to engineering-oriented programs. The term interest rate paid is more appropriate for the borrower's perspective, while rate of return earned is better from the investor's perspective.

Engineering alternatives are evaluated upon the prognosis that a reasonable rate of return (ROR) can be realized. A reasonable rate must be established so that the accept/reject decision can be made. The reasonable rate, called the minimum attractive rate of return (MARR), must be higher than the cost of money used to finance the alternative, as well as higher than the rate that would be expected from a bank or safe (minimal risk) investment. For a corporation, the MARR is always set above its cost of capital, that is, the interest rate a company must pay for capital funds needed to finance projects. For example, if a corporation can borrow capital funds at an average of 5% per year and expects to clear at least 6% per year on a project, the minimum MARR will be 11% per year.[15]

5.2 Present Worth Analysis

A future amount of money converted to its equivalent value now has a present worth (PW) that is always less than that of the actual cash flow, because for any interest rate greater than zero, all P/F (find present worth given future worth) factors have a value less than 1.0. For this reason, present worth values are often referred to as discounted cash flows (DCF). Similarly, the interest rate may be referred to as the discount rate. Besides PW, equivalent terms frequently used are present value (PV) and net present value (NPV). Up to this point, present worth computations have been made for one project. In this chapter, techniques for comparing two or more mutually exclusive alternatives by the present worth method are treated. Additionally, techniques that evaluate capitalized costs, life cycle costs, and independent projects are discussed.

5.2.1 Present Worth Analysis of Equal – Life Alternatives:

In present worth analysis, the P value, now called PW, is calculated using the MARR for each alternative. This converts all future cash flows into present dollar equivalents. This makes it easy to determine the economic advantage of one alternative over another.

The PW comparison of alternatives with equal lives is straightforward. If both alternatives are used in identical capacities for the same time period, they are termed equal-service alternatives, otherwise, specific methods must be used to assume equal life time such as least common multiple and specified study period. For mutually exclusive alternatives the following guidelines are applied:

One alternative: Calculate PW at the MARR. Two or more alternatives: Calculate the PW of each alternative at the MARR. Select the alternative with the PW value that is numerically largest, that is, less negative or more positive.[14]

5.2.2 Present Worth Analysis for both systems

The comparison between the Electric Heat Pump & the Diesel Boiler based on the power rating, annual consumption, annual maintenance & operating cost, salvage values for both systems during the same life cycle & the same operating hours during the year, In order to obtain the most benefit alternative from economical point of view, all the up mentioned values must be reflected to the present worth (PW) to solve the problem based on 10% rate of return.

Table (5.1): Present Worth Analysis for both Electric Heat Pump & Diesel Boiler.

	Heat Pump	Diesel Boiler
Heating Load (kW)	6.11	6.11
Consumption (Unit/day)	23.42 (kWh/day)	8.82 (L/day)
Consumption (Unit/year)	2810.4 (kWh/year)	1058.4 (L/year)
Heat Energy Required to cover the Load for the Area (kWh/year)	8798.4	8798.4
Annual Operating hours (12 Hours/day) during winter season (120 days)	1440	1440
Initial Cost (P) (NIS)	35500	16000
Salvage Value (SV) (NIS)	3550	1600
Annual cost and Maintenance (AOC) (NIS/year)	2135.6	7141.5
Life Time (n) (years)	15	15

$$PW_{UFHP} = -P_{UFHP} - AOC_{UFHP}\left(\frac{P}{A}, 10\%, 15\right) + SV_{UFHP}(\frac{P}{F}, 10\%, 15)$$

In a similar manner, the PW of the DB was calculated

$$PW_{DB} = -P_{DB} - AOC_{DB}\left(\frac{P}{A}, 10\%, 15\right) + SV_{DB}(\frac{P}{F}, 10\%, 15)$$

PW_{UFHP} = - 35500 – 458.54 * (P/A , i 10% , n = 15) + 3550 * (P/F , i 10% , n = 15)

= -35500 – 2135.6 * 7.606 + 3550 * 0.2394

= - 50893.5

PW_{DB} = -16000 – 1588 * (P/A , i 10% , n = 15) + 1600 * (P/F , i 10% , n = 15)

= -16000 – 7141.5 * 7.606 + 1600 * 0.2394

= - 69935.2

Now the status is obvious here that the UFHP (Under Floor Heat Pump) is the best alternative from an economical point of view since it costs less than DB alternative. Economic factors of interests rates applied in the above analysis are given in Appendix (D).

Chapter Six

Environmental Impact Analysis of a Heat Pump VS Diesel Boiler

Chapter Six

Environmental Impact Analysis of a Heat Pump VS Diesel Boiler

6.1 Introduction

Energy utilization and consumption in buildings is one of the most important aspects that have to be addressed in the near future. Around 40% of the primary energy use within Europe is related to the building sector. The energy utilization in the built environment has to go through a transition. Up to now most of our space conditioning systems are major contributors to global warming. Environmentally friendly heating systems have to be introduced on a large scale in order to reduce the emissions of greenhouse gases. ECO-Labeling of such environmentally benign systems is one way to encourage and guide customers in their choice of products.

One of the most promising technologies to reduce greenhouse gas emissions is provided by electric heat pumps. Heat pumps offer an energy efficient way to provide space heating and preparation of sanitary hot water. Even though technical know-how of the heat pumping technology is well proven, it has not yet reached public recognition worldwide. In Europe, a sustainable market has only been established in small countries like Sweden, Switzerland and parts of Austria. Due to the escalating price of oil and electricity in conjunction with the increase of energy related taxes and growing environmental concern, the market for heat pumps have started to grow in all of Europe.[15]

The word heat pump is a collective term for a wide range of products utilizing the same working principle. There are however many different types of heat pumps, all of which most suitable for different applications. Heat pumps are in general divided into different types depending on which heat source and heat sink they are designed for. All types have their own pros and cons as well as environmental impact. The most important aspects to consider during an evaluating of different heat sources are; availability, temperature level, annual temperature fluctuations and investment cost attributed to the choice of heat source. In reality the choice will be limited due to prevailing local conditions.[15]

Ambient air is by far the most common heat source for heat pump applications worldwide. The reason to this is the unlimited availability that enables an uncomplicated and quick installation. In most European climates the temperature of ambient air, changes significantly depending on the time of year. The fact that the performance of a heat pump is reduced as the temperature of the heat source drops, lead to unfavorable characteristics. The performance of an ambient air heat pump will decrease as the heating demand is increasing. At a certain point the temperature difference between the heat source and heat sink will be too great for the heat pump to operate at all and the heat pump has to be stopped. For most ambient air heat pumps, this will occur at temperatures in the range of (–15°C)-(-20°C). In cold climates this raises the demand for an auxiliary heating system that is designed for the maximum heat load of the building. Heat pumps are unique in the sense that one and the same appliance are able to provide heating as well as cooling. Keeping in mind that more than 15000 people died during the heat wave 2003, space cooling is in many parts of Europe not only a matter of comfort, but a necessity for human well-being. A major quantity of all air source heat pumps is designed for dual use, heating as well as cooling. Cooling may be achieved by simply reversing the cycle. Small air source heat pumps sold in the southern part of Europe are mainly used for cooling purposes, whereas the same unit sold in the northern part of Europe will be used for heating.

The use of the ground as heat source for heat pumps enables the use of renewable energy stored in the soil or bedrock. The ground serves as seasonal storage of solar energy. At a depth of 0.9-1.5 m the amplitude of temperature change due to changes of outdoor temperature is damped and delayed. This results in very favorable working conditions for a heat pump extracting energy from the ground. The heat exchanger may either be designed for horizontal installation in the ground soil or a vertical installation. The vertical heat exchangers are most commonly installed in deep boreholes in embedded bedrock. The horizontal loops are generally cheaper to install than the vertical systems. The vertical systems are however requiring much less surface area. The ground may additionally serve as a heat sink for cooling applications or as in some systems, which are designed for ”free-cooling”, provide comfort cooling at almost no electric input at all.

Exhaust air, ground water and surface water (e.g. lake, river or pond) are other examples of commonly used heat sources. The overall efficiency of a heat pump system, which is called the coefficient of performance (COP), is not only dependent on the efficiency of the appliance. However, the same appliance will generate quite different annual efficiency factors depending on the temperature levels of the heat source and the heat distribution system. An experienced installer is required, in order to achieve appropriate design according to the unique conditions. There is a strong need for competence among the installers in order to develop a successful market. Several markets have experienced periods of bad repute due to the lack of qualified installers. The need for trained installers is well known and has initiated a joint certification project within the European Union. The aim of the project is to develop a general basis for a European certification scheme for heat pump installers and initiate pilot courses in each participating country. Austria and Sweden are already offering several different training options for installers, whereas most other countries are at the stage of developing training courses.[15]

Unit performance is tested according to the European standard EN-14511 by accredited test institutes. Growing interest for the technology has intensified research and development, which has led to significant improvement of the efficiency during the last decade. In comparison to a conventional boiler a highly efficient heat pump system will reduce the use of fossil fuel and reduce hazardous emissions locally. Depending on the generation of electricity emissions do occur at the plant site. Utility plants are however in general generating lower emission rates than small domestic furnaces. The indirect emissions from heat pumps are thus dependent on the efficiency of the heat pump system as well as the efficiency of the plant generating the electricity. Mitigation of emissions is the most pronounced environmental benefit offered by heat pumps. The magnitude of the possible benefits will vary, depending on the local generation of electricity.

However, heat pumps do contribute to direct emissions by means of refrigerant leakage over their lifecycle. In addition to leakage that occurs during operation, losses will occur at demolition of the appliance. The impact of these losses on the environment will depend on the refrigerant in use. The most commonly used refrigerants today are hydro-flouro-carbons (HFC). These refrigerants have no ozone depletion potential , but they are contributing to global warming and should therefore be used with care. In order to improve the control of HFCs the European commission has proposed a new directive on restrictive use of F-gases (HFCs, per-fluorocarbons or PFCs and sulphur hexafluoride or SF6). The first part is dealing with the phase out of R-134a from vehicle air-conditioning. The second part apply to domestic and commercial refrigeration, air-conditioners, heat pumps, firefighting appliances, health care, etc. The overall aim of the second part of the new directive is to improve the control of HFCs by setting minimum standards for inspection and recovery. Regulations regarding monitoring and reporting on leakage are strengthened, including training and certification of personnel in charge of inspections. Labeling of products is introduced in order to improve the information to the consumers.[15]

Environmental evaluations of heat pump applications need to take into account for indirect emissions related to the generation of electricity that is used to operate the heat pump, as well as direct emissions of the refrigerant. A lot of research has been made on the establishment of an integrated method to calculate the contribution of greenhouse gas emissions from refrigeration and heat pump applications. The most well established method, TEWI (Total Equivalent Warming Impact), was developed at Oak Ridge National Laboratory in the early nineties. A TEWI calculation integrates direct and indirect greenhouse gas emissions over the whole lifetime into a single number expressed in terms of CO_2 mass equivalents. The TEWI concept is used in the newly developed criteria for eco-labeling of electrically driven heat pumps under "Der blaue engel" in Germany.

Estimation of CO_2-emissions is an essential exercise in the evaluation of environmental performance. There are however other measures to compare the performance of different systems available. The concept of primary energy ratio (PER) is merely the relation between useful energy output divided by necessary energy input. This value gives a direct value of the overall efficiency for a complete system, taking in to account for losses related to the generation of electricity. For a common combustion appliance the PER value is equal to the overall efficiency of the system.

6.2 Environmental Impact Related to the use of Heat pumps

With the exception of a few technologies, the majority of all life cycle assessments carried out on systems for space conditioning or generation of electricity by combustion, confirm that most of the environmental impact stems from the appliance/plant in operation. Environmental evaluations of heat pump applications need to take into account for indirect emissions related to the generation of electricity that is used to operate the heat pump, as well as direct emissions of the refrigerant.

The new methodology for electricity-specific factors is also applied to address two further limitations with the composite factors: firstly the composite factors are only for CO_2 emissions, and do not cover the other relevant Kyoto gases; and secondly they are only for emissions per kWh generated, and do not provide factors for transmission and distribution (T&D) losses, or emissions per kWh of electricity consumed. Using the new electricity-specific methodology provides factors for CO_2, CH_4 and N_2O, and emission factors for T&D losses and for "consumed" electricity. The methodology for electricity-specific emission factors involves calculating the total emissions from the generation of electricity within a country and dividing that figure by the total amount of electricity produced by the country. Data for the quantities of different fossil fuels combusted within dedicated electricity plants, and also within combined heat and power (CHP) plants. Total emissions were calculated from these data by applying the appropriate default emission factors from the Guidelines for National Greenhouse Gas Inventories.

The simplest formula for calculating the Amount of CO_2 produced from Heat pump unit is:

$$CO2\ Produced\ from\ HP\ unit = \text{Energy Produced (kWh)} * \text{Factor} \left(\frac{\text{CO2}}{\text{kWh}}\right) \text{(Table in App(A) special for Israel)}$$

$$CO2\ (kg) = \text{Energy Produced (kWh)} * 0.74 \left(\frac{\text{CO2}}{\text{kWh}}\right)$$

$$CO2\ Produced\ from\ DB\ unit = \text{Energy Produced (kWh)} * \text{Factor} \left(\frac{\text{CO2}}{\text{kWh}}\right) [19]$$

$$CO2\ (kg) = \text{Energy Produced (kWh)} * 0.25 \left(\frac{\text{CO2}}{\text{kWh}}\right)$$

Table (6.1) Comparison between Diesel Boiler & Heat Pump Systems based on CO_2 Emissions.

	Heat Pump	**Diesel Boiler**
Heating Load (kW)	**6.11**	**6.11**
Consumption (Unit/day)	**23.42 (kWh/day)**	**8.82 (L/day)**
Consumption (Unit/year)	**2810.4 (kWh/year)**	**1058.4 (L/year)**
Heat Energy Required (kWh/year)	**8798.4**	**8798.4**
Annual Operating hours (12 Horurs/day) during winter season	**1440**	**1440**
Produced CO2	**0.74 (kg CO2/kWh) Electrical Energy**	**0.25 (kg CO2/kWh) Heat Energy**
Total Tons of CO2/life cycle	**31.2**	**32.99**
Life Time(years)	**15**	**15**

The achieved results show that the CO_2 Emission for Heat Pump is less than emission for diesel boiler, thus, it helps in reducing the Greenhouse effect produced from this system.

Chapter Seven

Conclusion & Results Analysis

Chapter Seven
Conclusion & Results Analysis

7.1 Conclusion & Discussion

In the study of Heat Pump system for Heating an under floor area, the energy consumption of the system has been calculated and compared with the energy consumption in the under floor heating system using Diesel Boiler, the basic for this idea comes from the concept of HP, that consists of multiplying the electric energy input to the system by more than three times i.e (COP = 3.13) in such case, but the relation discussing the performance of the diesel boiler consists of the concept of Efficiency i.e. the amount of diesel that consumed by the burner can't be converted completely to heat energy without losses, these losses decrease the efficiency of the boiler in heating systems. A lot of relations has been discussed in this thesis to clarify the behavior of each system.

In the other hand, the Heat Pump System could be satisfied environmentally because it produces (31.2 Tons CO_2/Life Cycle) comparing with (32.99 TonsCO_2/Life Cycle) for the Diesel Boiler system. Heat Pump System is economically feasible more than the Diesel Boiler System in the economic calculations.

7.2 Decision making criteria for both systems

After the comparison between both systems, the more feasible system has to be selected to be used, but the selection criteria must be based on combination from both economic & environmental impacts.

WSM (Weighted Sum Method is the most commonly used approach in sustainable energy systems, The score of an alternative is calculated as, Table (7.1) [16] clarifies the difference between using both Electric Heat Pump & Diesel Boiler in economical & environmental points of view.

Table (7.1): Decision matrix - Economical & Environmental results for both systems.

	Economy	Environment
Diesel Boiler	(PW) 14030.4	32.99 (Ton CO_2/kWh/15 years of Life Cycle)
Electric Heat Pump	(PW) 5830.19	31.2 (Ton CO_2/kWh/15 years of Life Cycle)

$$S_i = \sum_{j=1}^{n} w_j x_{ij}, \quad i = 1, 2, \ldots, m$$

Eq. (7.1)

Then the resulting cardinal scores for each alternative can be used to rank, screen, or choose an alternative. The best alternative is the one whose score is the maximum. But in this case of study, the results clear that the UFHP is normally dominating comparing with the Diesel Boiler.

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Appendices

Appendix A: Electricity Specific Factors

	Electricity-specific factors ($kgCO_2/kWh$)	IEA composite electricity/heat factors ($kgCO_2/kWh$)	Difference (gCO_2/kWh)	Difference (%)
India	1.333174843	0.9682265	0.36495	37.7%
Indonesia	0.684693977	0.726138	-0.04144	-5.7%
Iran, Islamic Republic of	0.631113877	-	-	-
Iraq	0.820614626	0.812045	0.00857	1.1%
Ireland	0.521193132	0.486205	0.03499	7.2%
Israel	0.740303524	0.6932951	0.04701	6.8%
Italy	0.410898038	0.398464	0.01243	3.1%
Jamaica	0.796106233	0.7846682	0.01144	1.5%
Japan	0.443356848	0.436453	0.00690	1.6%
Jordan	0.643924449	0.5889758	0.05495	9.3%
Kazakhstan	0.923181405	0.4388794	0.48430	110.3%
Kenya	0.332297783	0.3285304	0.00377	1.1%

Appendix B: Technical Data & Specifications for Diesel Boiler (Ferroli)

			Combination	
			25c	30c
Ferroli product codes - Natural Gas			0T1R2JGA	0T1R3JGA
Ferroli product codes - LPG			ZU0T1R2JGA	ZU0T1R3JGA
Warranty			5yr	5yr
NO_x emissions class (mg/kWhr)			5	5
Energy marking rating (92/42 EEC directive)			★★★★	★★★★
SAP 2009 annual/2005 seasonal efficiency %		NG	89.2/90.3	89.2/90.3
		LPG	90.4/92.2*	90.4/92.2*
Output max/min				
Heat input		kW	25.0/5.8	29.5/6.7
Useful heat output 80°C – 60°C		kW	24.5/5.7	28.9/6.6
Useful heat output 50°C – 30°C		kW	26.5/6.2	31.3/7.2
Central heating				
Maximum operating temperature		°C	90	90
Operating pressure central heating	Max.	bar	3	3
	Min.	bar	0.8	0.8
Expansion vessel capacity		litres	8	10
Expansion vessel pre-fill pressure		bar	0.8	0.8
Boiler water content		litres	1.7	2.1
DHW				
Maximum DHW production	Δt 25°C	l/min	15.5	18.3
	Δt 30°C	l/min	12.9	15.3
	Δt 35°C	l/min	11.1	13.1
Operating pressure DHW	Max.	bar	9	9
	Min.	bar	0.3	0.3
Dimensions & weights				
Height		mm	600	600
Width		mm	400	400
Depth		mm	320	320
Weight (empty)		kg	29	31.5
Fittings				
Gas fitting		mm	22	22
Central heating fittings		mm	22	22
DHW circuit fittings		mm	15	15
Power supply				
Max power input		W	100	120
Power supply voltage/frequency		V/Hz	230V/50Hz	230V/50Hz
Index of protection		IP	IPX5D	IPX5D
Maximum equivalent flue lengths				
Max horizontal flue length 60/100mm Ø		m	7	7
Max vertical flue length 60/100mm Ø		m	8	8
Max horizontal flue length 80/125mm Ø		m	28	28
Max vertical flue length 80/125mm Ø		m	28	28
Total equivalent length two pipe 80mm Ø		m	80	70

Technical Data & Specifications for Diesel Boiler (Ferroli)

Appendix C: Relations & Figures

HP Relations / (T_{Min} & Q_{HL})

1- For February - 2011

Feb.2011	**T**	**Q (Heating Load)**
Day No.	**Min.**	**kW**
1	4.5	1.642
2	4	1.665
3	2.4	1.736
4	5.5	1.597
5	5	1.620
6	5	1.620
7	7	1.530
8	6.5	1.552
9	6	1.575
10	6	1.575
11	5.4	1.602
12	5	1.620
13	5	1.620
14	5.2	1.611
15	7.4	1.512
16	7	1.530
17	6.5	1.552
18	7	1.530
19	11	1.350
20	8.4	1.467
21	7	1.530
22	6.5	1.552
23	10	1.395
24	9	1.440
25	10.5	1.373
26	5.6	1.593
27	6.2	1.566
28	7	1.530

Table (C-1)

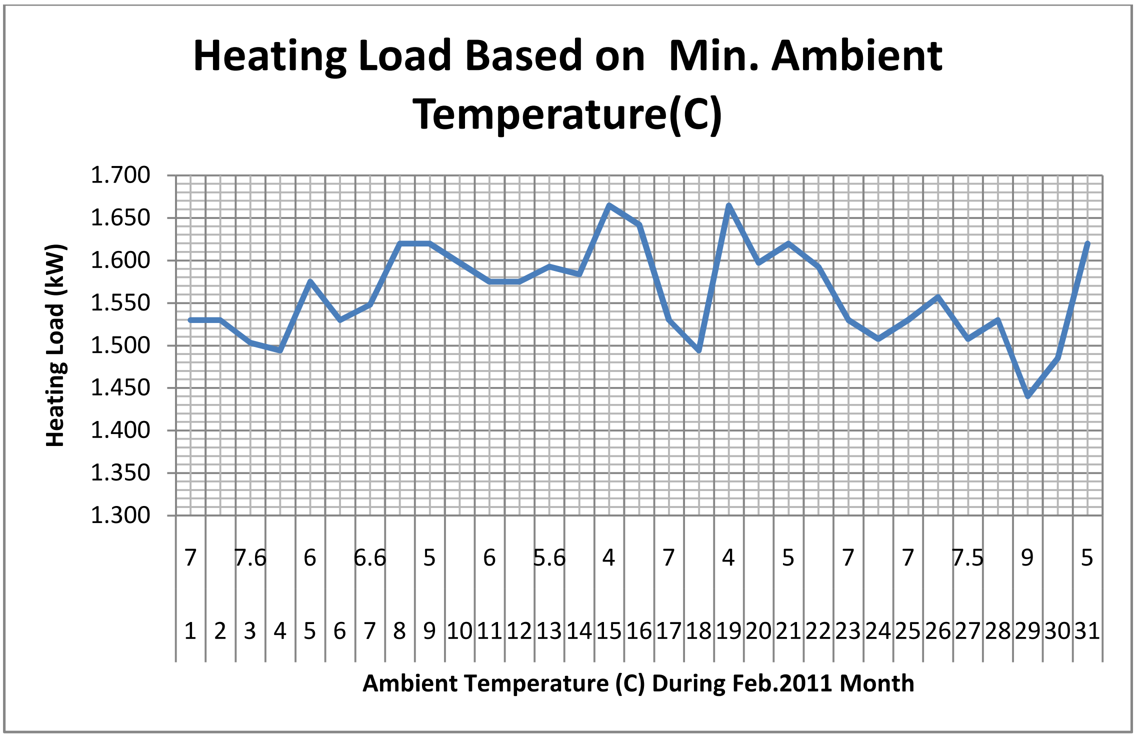

Heating Load Based on Min. Ambient Temperature(C)
Heating Load (kW)
1.700
1.650
1.600
1.550
1.500
1.450
1.400
1.350
1.300
7
7.6
6
6.6
5
6
5.6
4
7
4
5
7
7
7.5
9
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Ambient Temperature (C) During Feb.2011 Month

Figure (C-1)

2- For Novembre – 2011

Nov.2011	**T**	**Q (Heating Load)**
Day No.	**Min.**	**kW**
1	10	1.395
2	10	1.395
3	11	1.350
4	11.8	1.315
5	9	1.440
6	9	1.440
7	9	1.440
8	9.4	1.422
9	9	1.440
10	11.6	1.324
11	12	1.306
12	14	1.216
13	9	1.440
14	11	1.350
15	7	1.530
16	6.6	1.548
17	9	1.440
18	8.4	1.467
19	7.8	1.494
20	6.4	1.557
21	7	1.530
22	6	1.575
23	8	1.485
24	8.5	1.463
25	7.4	1.512
26	4	1.665
27	4	1.665
28	4.6	1.638
29	5	1.620
30	6.8	1.539

Table (C-2)

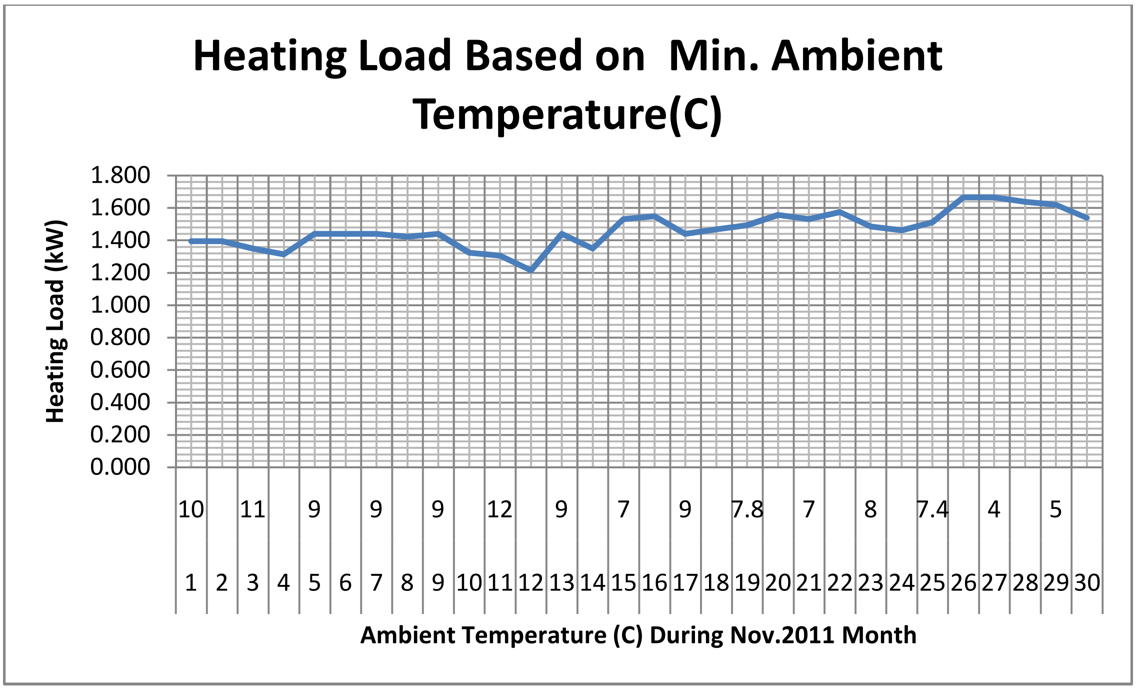

Heating Load Based on Min. Ambient Temperature(C)
Heating Load (kW)
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
10
11
9
9
9
12
9
7
9
7.8
7
8
7.4
4
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Ambient Temperature (C) During Nov.2011 Month

Figure (C-2)

3- For December – 2011

Dec.2011	T	Q (Heating Load)
Day No.	**Min.**	**kW**
1	6.6	1.548
2	6.4	1.557
3	8	1.485
4	8.6	1.458
5	8	1.485
6	7.6	1.503
7	7	1.530
8	7.6	1.503
9	6	1.575
10	5	1.620
11	2.6	1.727
12	6	1.575
13	6.6	1.548
14	9.8	1.404
15	7.4	1.512
16	6	1.575
17	7	1.530
18	7.6	1.503
19	9	1.440
20	12	1.306
21	10.8	1.359
22	8	1.485
23	6.6	1.548
24	6	1.575
25	4	1.665
26	6	1.575
27	5	1.620
28	4	1.665
29	6	1.575
30	7.4	1.512
31	5	1.620

Table (C-3)

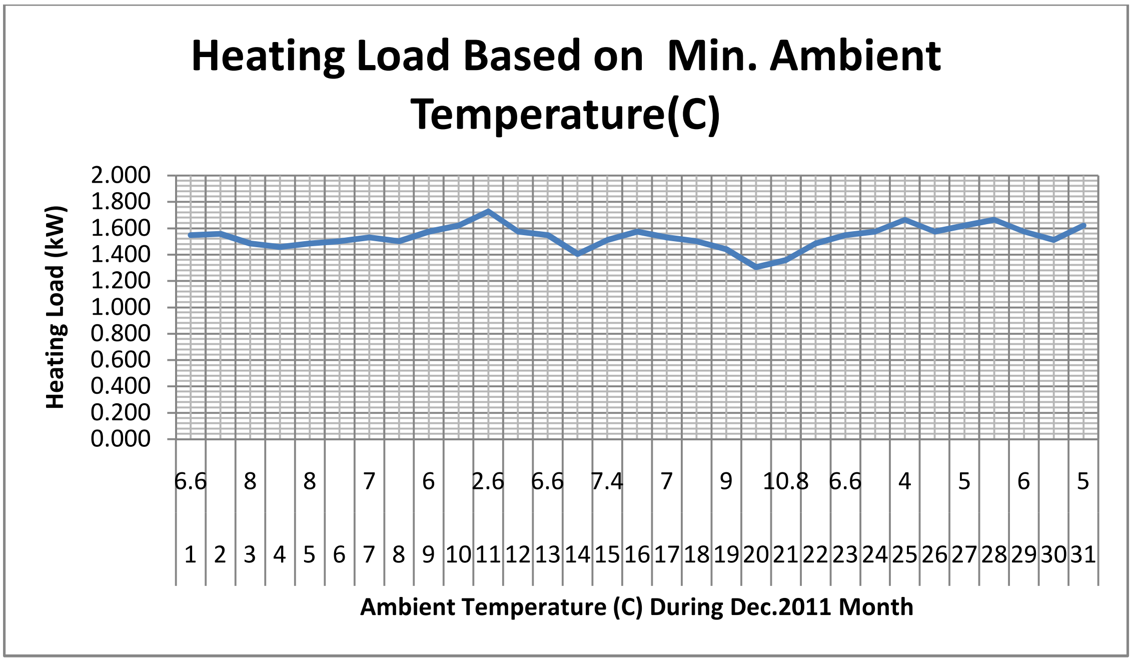

Heating Load Based on Min. Ambient Temperature(C)
Heating Load (kW)
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
6.6 8 8 7 6 2.6 6.6 7.4 7 9 10.8 6.6 4 5 6 5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Ambient Temperature (C) During Dec.2011 Month

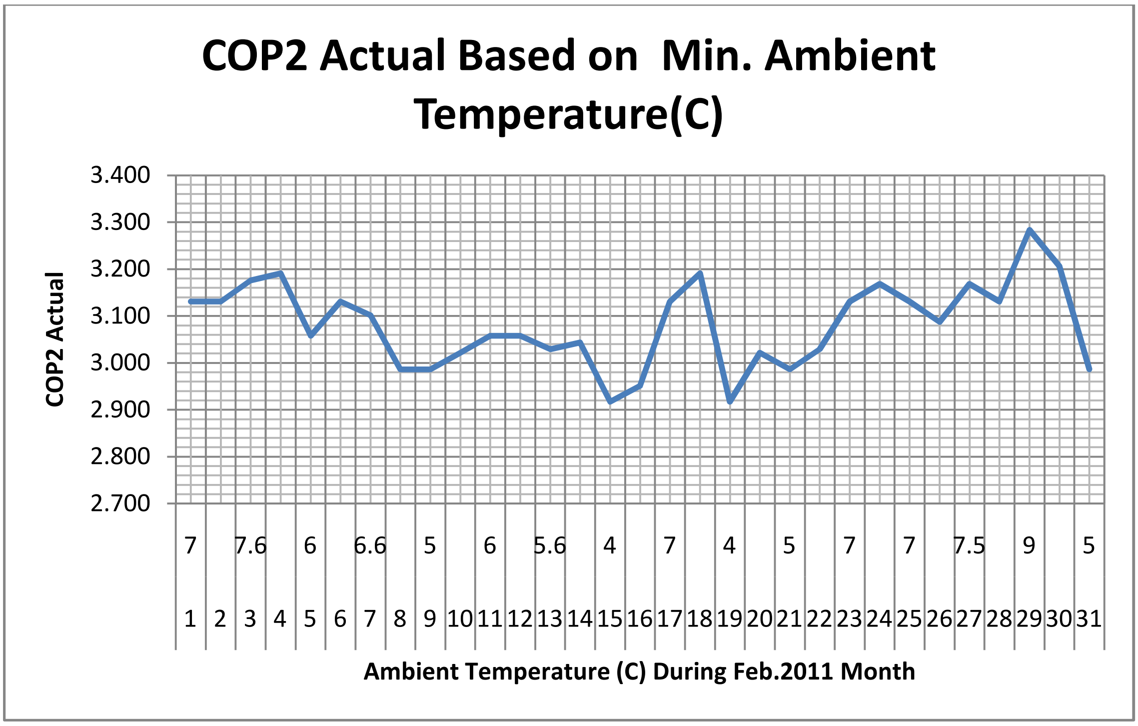
Figure (C-3)

HP Relations / (T_{Min} & COP2)

1- For February – 2011

Feb.2011	T	COP2=QHP/PI
Day No.	Min.	From Manf. Capacity Tables
1	4.5	2.952
2	4	2.917
3	2.4	2.811
4	5.5	3.022
5	5	2.987
6	5	2.987
7	7	3.131
8	6.5	3.094
9	6	3.058
10	6	3.058
11	5.4	3.015
12	5	2.987
13	5	2.987
14	5.2	3.001
15	7.4	3.161
16	7	3.131
17	6.5	3.094
18	7	3.131
19	11	3.444
20	8.4	3.237
21	7	3.131
22	6.5	3.094
23	10	3.363
24	9	3.284
25	10.5	3.404
26	5.6	3.029
27	6.2	3.072
28	7	3.131

Table (C-4)



COP2 Actual Based on Min. Ambient Temperature(C)
3.400
3.300
3.200
3.100
3.000
2.900
2.800
2.700
COP2 Actual
7
7.6
6
6.6
5
6
5.6
4
7
4
5
7
7
7.5
9
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Ambient Temperature (C) During Feb.2011 Month

Figure (C-4)

2- For November – 2011

Nov.2011	T	COP2=QHP/PI
Day No.	Min.	From Manf. Capacity Tables
1	10	3.363
2	10	3.363
3	11	3.444
4	11.8	3.511
5	9	3.284
6	9	3.284
7	9	3.284
8	9.4	3.315
9	9	3.284
10	11.6	3.494
11	12	3.528
12	14	3.701
13	9	3.284
14	11	3.444
15	7	3.131
16	6.6	3.102
17	9	3.284
18	8.4	3.237
19	7.8	3.191
20	6.4	3.087
21	7	3.131
22	6	3.058
23	8	3.206
24	8.5	3.245
25	7.4	3.161
26	4	2.917
27	4	2.917
28	4.6	2.959
29	5	2.987
30	6.8	3.116

Table (C-5)

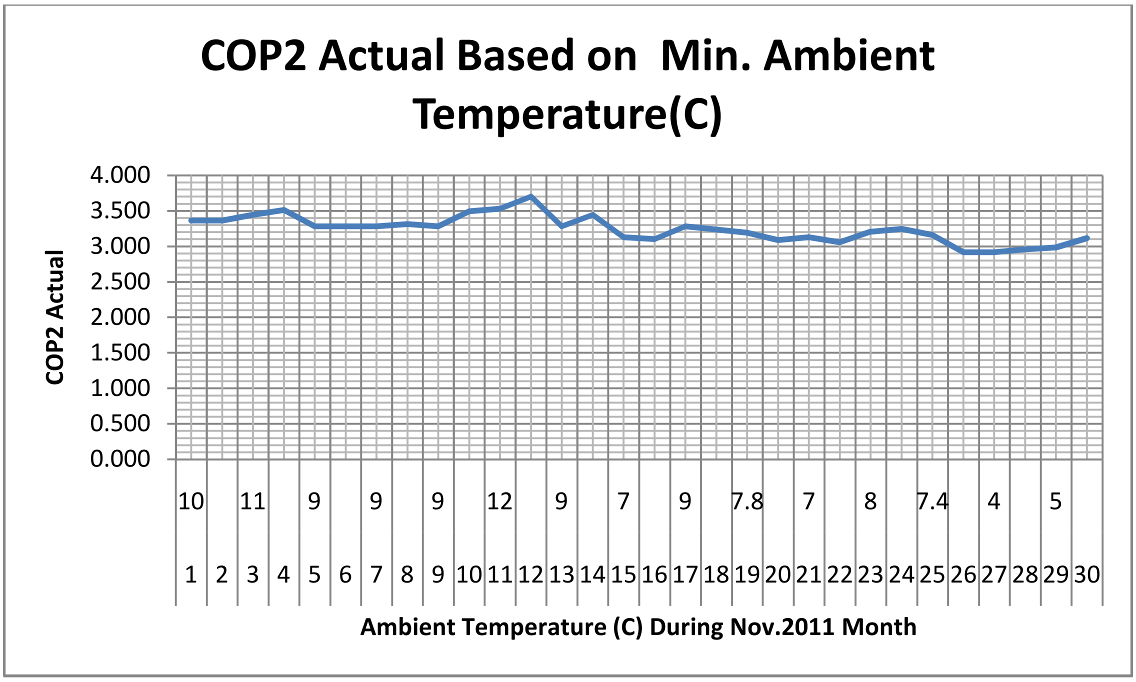

COP2 Actual Based on Min. Ambient Temperature(C)
COP2 Actual
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
10 11 9 9 9 12 9 7 9 7.8 7 8 7.4 4 5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Ambient Temperature (C) During Nov.2011 Month

Figure (C-5)

3- For December – 2011

Dec.2011	**T**	**COP2=QHP/PI**
Day No.	**Min.**	**From Manf. Capacity Tables**
1	6.6	3.102
2	6.4	3.087
3	8	3.206
4	8.6	3.253
5	8	3.206
6	7.6	3.176
7	7	3.131
8	7.6	3.176
9	6	3.058
10	5	2.987
11	2.6	2.824
12	6	3.058
13	6.6	3.102
14	9.8	3.347
15	7.4	3.161
16	6	3.058
17	7	3.131
18	7.6	3.176
19	9	3.284
20	12	3.528
21	10.8	3.428
22	8	3.206
23	6.6	3.102
24	6	3.058
25	4	2.917
26	6	3.058
27	5	2.987
28	4	2.917
29	6	3.058
30	7.4	3.161
31	5	2.987

Table (C-6)

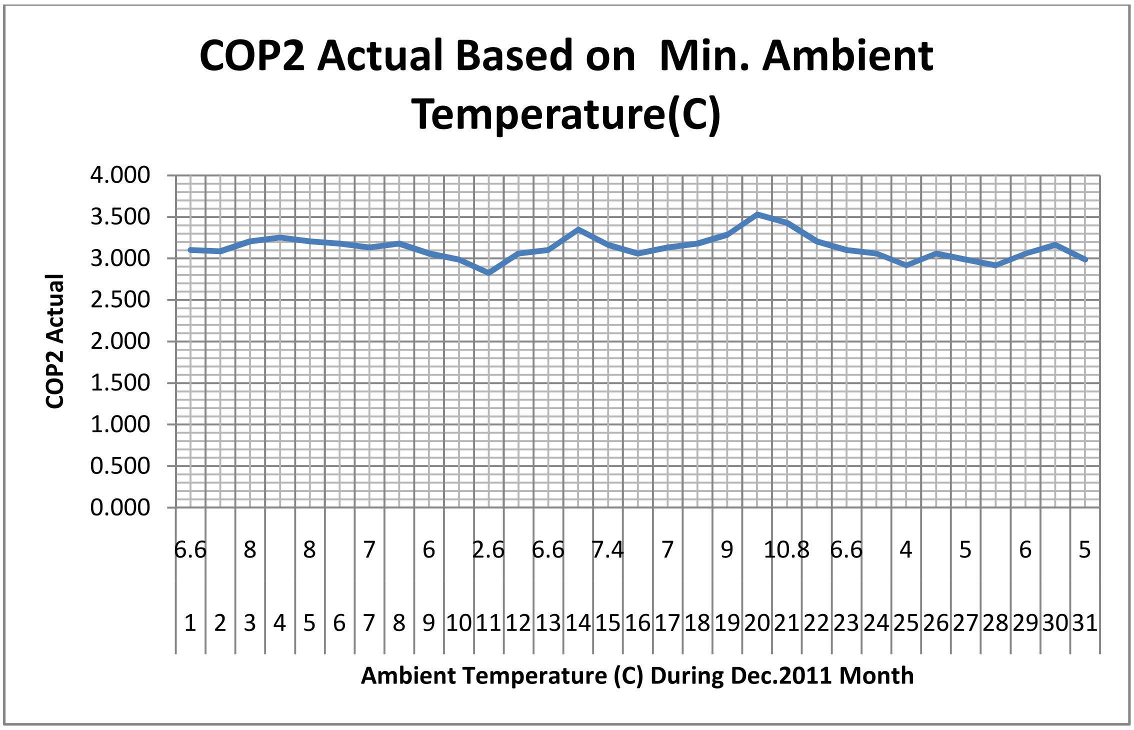

COP2 Actual Based on Min. Ambient Temperature(C)
COP2 Actual
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
6.6 8 8 7 6 2.6 6.6 7.4 7 9 10.8 6.6 4 5 6 5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Ambient Temperature (C) During Dec.2011 Month

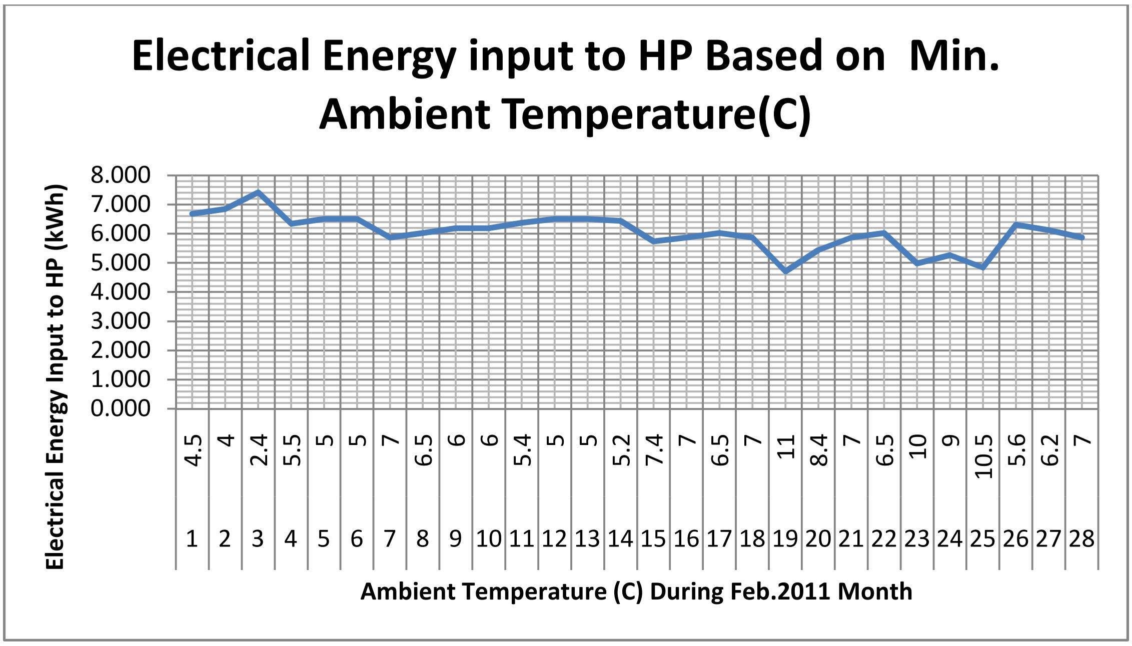
Figure (C-6)

HP Relations / (T_{Min} & Electrical Energy Consumption)

1- For February – 2011

Feb.2011 Day No.	T Min.	Electrical Energy input to HP (kWh)/day
1	4.5	6.676
2	4	6.847
3	2.4	7.413
4	5.5	6.343
5	5	6.508
6	5	6.508
7	7	5.864
8	6.5	6.021
9	6	6.180
10	6	6.180
11	5.4	6.376
12	5	6.508
13	5	6.508
14	5.2	6.442
15	7.4	5.740
16	7	5.864
17	6.5	6.021
18	7	5.864
19	11	4.705
20	8.4	5.439
21	7	5.864
22	6.5	6.021
23	10	4.979
24	9	5.263
25	10.5	4.841
26	5.6	6.310
27	6.2	6.116
28	7	5.864

Table (C-7)



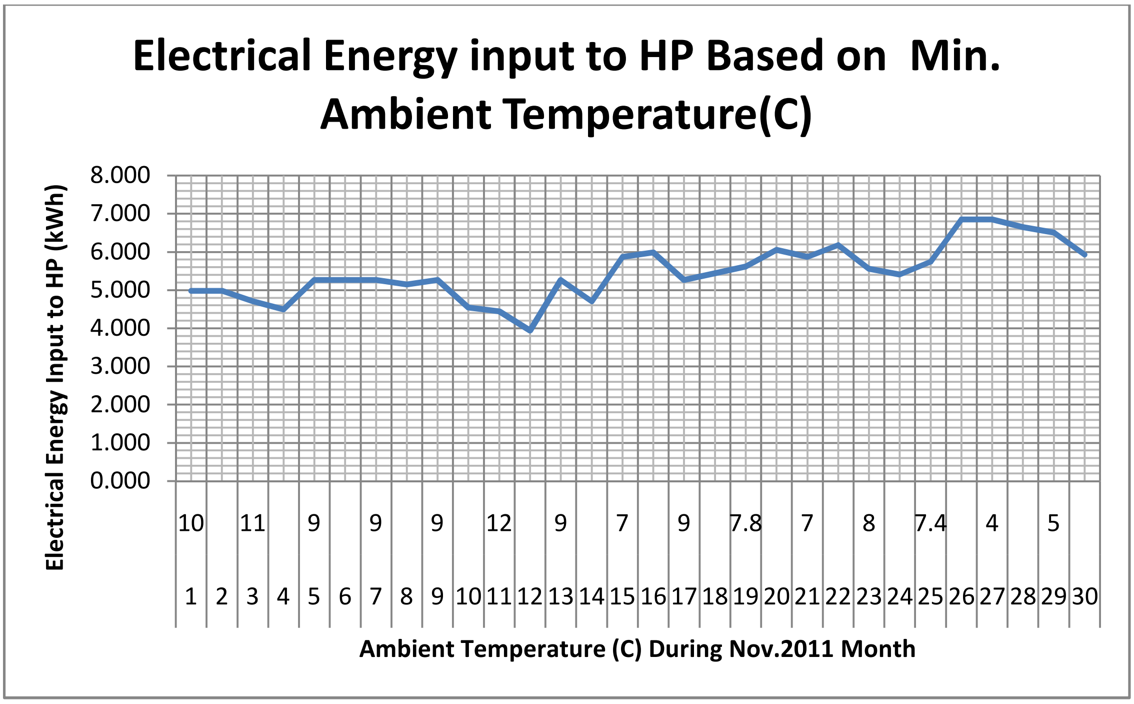
Electrical Energy input to HP Based on Min. Ambient Temperature(C)
Electrical Energy Input to HP (kWh)
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
4.5
4
2.4
5.5
5
5
7
6.5
6
6
5.4
5
5
5.2
7.4
7
6.5
7
11
8.4
7
6.5
10
9
10.5
5.6
6.2
7
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Ambient Temperature (C) During Feb.2011 Month

Figure (C-7)

2- For November – 2011

Nov.2011	T	Electrical Energy input to HP
Day No.	Min.	(kWh)/day
1	10	4.979
2	10	4.979
3	11	4.705
4	11.8	4.493
5	9	5.263
6	9	5.263
7	9	5.263
8	9.4	5.148
9	9	5.263
10	11.6	4.545
11	12	4.441
12	14	3.943
13	9	5.263
14	11	4.705
15	7	5.864
16	6.6	5.989
17	9	5.263
18	8.4	5.439
19	7.8	5.618
20	6.4	6.052
21	7	5.864
22	6	6.180
23	8	5.558
24	8.5	5.409
25	7.4	5.740
26	4	6.847
27	4	6.847
28	4.6	6.642
29	5	6.508
30	6.8	5.926

Table (C-8)



Electrical Energy input to HP Based on Min. Ambient Temperature(C)
Electrical Energy Input to HP (kWh)
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
10
11
9
9
9
12
9
7
9
7.8
7
8
7.4
4
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Ambient Temperature (C) During Nov.2011 Month

Figure (C-8)

3- For December – 2011

Dec.2011	**T**	**Electrical Energy input to HP**
Day No.	**Min.**	**(kWh)/day**
1	6.6	5.989
2	6.4	6.052
3	8	5.558
4	8.6	5.380
5	8	5.558
6	7.6	5.679
7	7	5.864
8	7.6	5.679
9	6	6.180
10	5	6.508
11	2.6	7.341
12	6	6.180
13	6.6	5.989
14	9.8	5.035
15	7.4	5.740
16	6	6.180
17	7	5.864
18	7.6	5.679
19	9	5.263
20	12	4.441
21	10.8	4.759
22	8	5.558
23	6.6	5.989
24	6	6.180
25	4	6.847
26	6	6.180
27	5	6.508
28	4	6.847
29	6	6.180
30	7.4	5.740
31	5	6.508

Table (C-9)

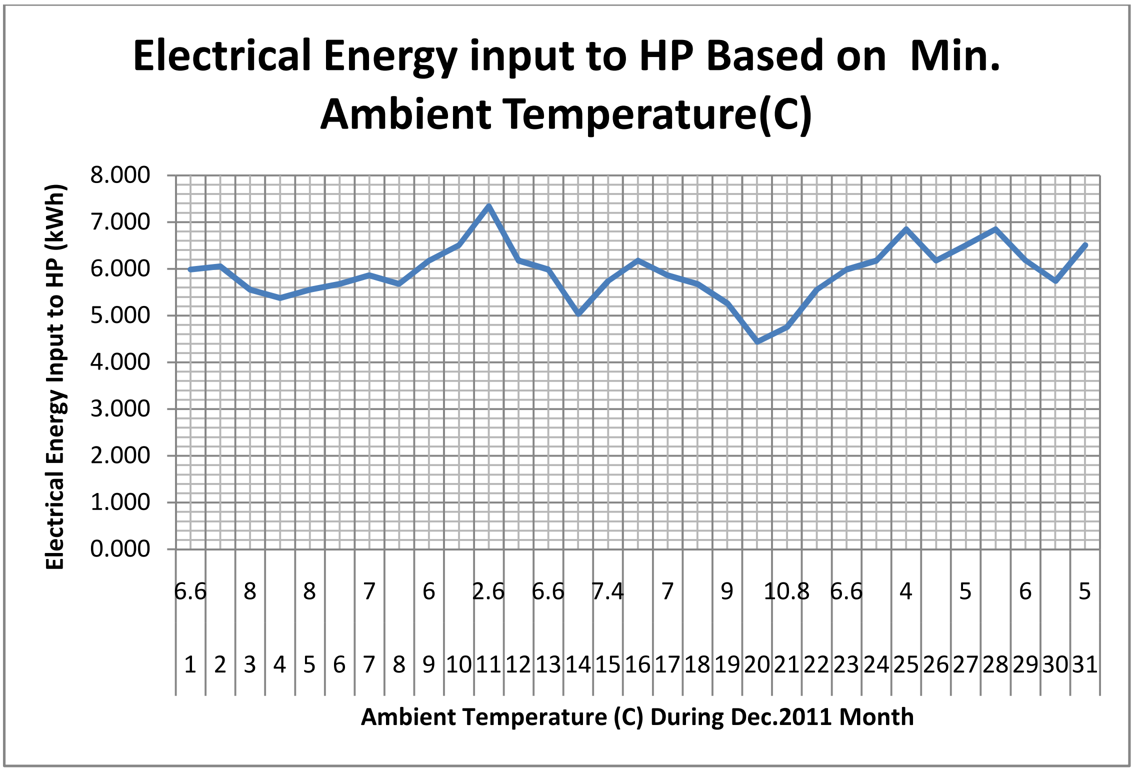

Electrical Energy input to HP Based on Min. Ambient Temperature(C)
Electrical Energy Input to HP (kWh)
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
6.6
8
8
7
6
2.6
6.6
7.4
7
9
10.8
6.6
4
5
6
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Ambient Temperature (C) During Dec.2011 Month

Figure (C-9)

Diesel Boiler Relations / (T_{Min} & Fuel Flow Rate):

1- For February – 2011.

Feb.2011	T	Fuel Flow Rate (kg/s)
Day No.	Min.	mf=QHL/(ζ*Heating Value)
1	4.5	0.000046
2	4	0.000046
3	2.4	0.000048
4	5.5	0.000045
5	5	0.000045
6	5	0.000045
7	7	0.000043
8	6.5	0.000043
9	6	0.000044
10	6	0.000044
11	5.4	0.000045
12	5	0.000045
13	5	0.000045
14	5.2	0.000045
15	7.4	0.000042
16	7	0.000043
17	6.5	0.000043
18	7	0.000043
19	11	0.000038
20	8.4	0.000041
21	7	0.000043
22	6.5	0.000043
23	10	0.000039
24	9	0.000040
25	10.5	0.000038
26	5.6	0.000044
27	6.2	0.000044
28	7	0.000043

Table (C-10) : The relation between the minimum ambient temperature & fuel consumption flow rate.

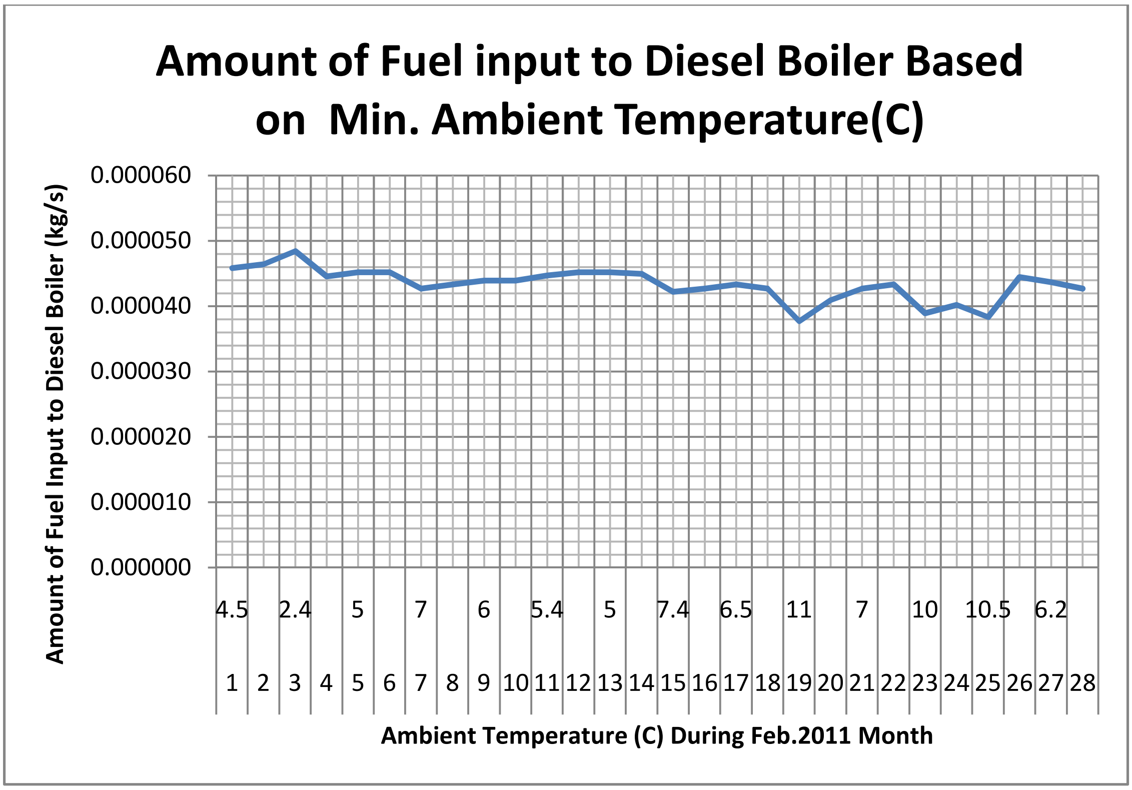


Figure (C-10) : The relation between the minimum ambient temperature & fuel consumption flow rate.

2 – For November – 2011.

Nov.2011	T	Fuel Flow Rate (kg/s)
Day No.	Min.	mf=QHL/(ζ*Heating Value)
1	10	0.000039
2	10	0.000039
3	11	0.000038
4	11.8	0.000037
5	9	0.000040
6	9	0.000040
7	9	0.000040
8	9.4	0.000040
9	9	0.000040
10	11.6	0.000037
11	12	0.000036
12	14	0.000034
13	9	0.000040
14	11	0.000038
15	7	0.000043
16	6.6	0.000043
17	9	0.000040
18	8.4	0.000041
19	7.8	0.000042
20	6.4	0.000043
21	7	0.000043
22	6	0.000044
23	8	0.000041
24	8.5	0.000041
25	7.4	0.000042
26	4	0.000046
27	4	0.000046
28	4.6	0.000046
29	5	0.000045
30	6.8	0.000043

Table (C-11) : The relation between the minimum ambient temperature & fuel consumption flow rate.

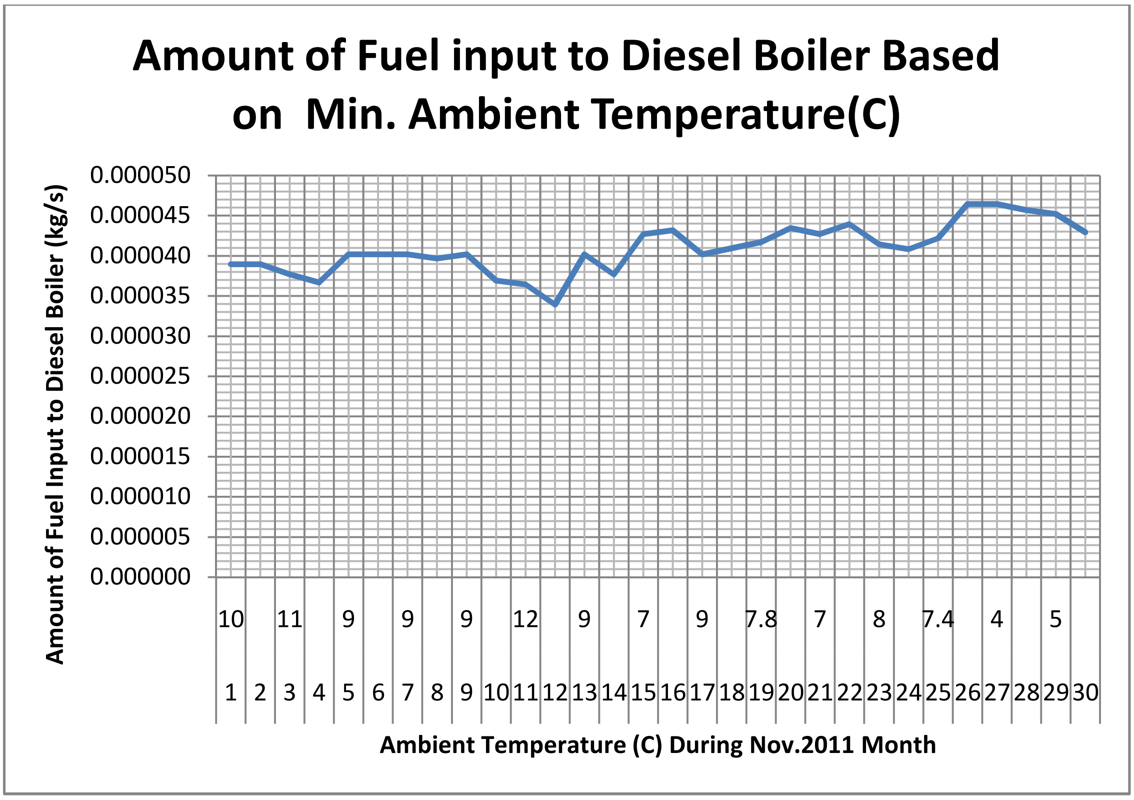


Figure (C-11) : The relation between the minimum ambient temperature & fuel consumption flow rate.

3 – For December – 2011

Dec.2011	T	Fuel Flow Rate (kg/s)
Day No.	Min.	mf=QHL/(ζ*Heating Value)
1	6.6	0.000043
2	6.4	0.000043
3	8	0.000041
4	8.6	0.000041
5	8	0.000041
6	7.6	0.000042
7	7	0.000043
8	7.6	0.000042
9	6	0.000044
10	5	0.000045
11	2.6	0.000048
12	6	0.000044
13	6.6	0.000043
14	9.8	0.000039
15	7.4	0.000042
16	6	0.000044
17	7	0.000043
18	7.6	0.000042
19	9	0.000040
20	12	0.000036
21	10.8	0.000038
22	8	0.000041
23	6.6	0.000043
24	6	0.000044
25	4	0.000046
26	6	0.000044
27	5	0.000045
28	4	0.000046
29	6	0.000044
30	7.4	0.000042
31	5	0.000045

Table (C-12) : The relation between the minimum ambient temperature & fuel consumption flow rate.

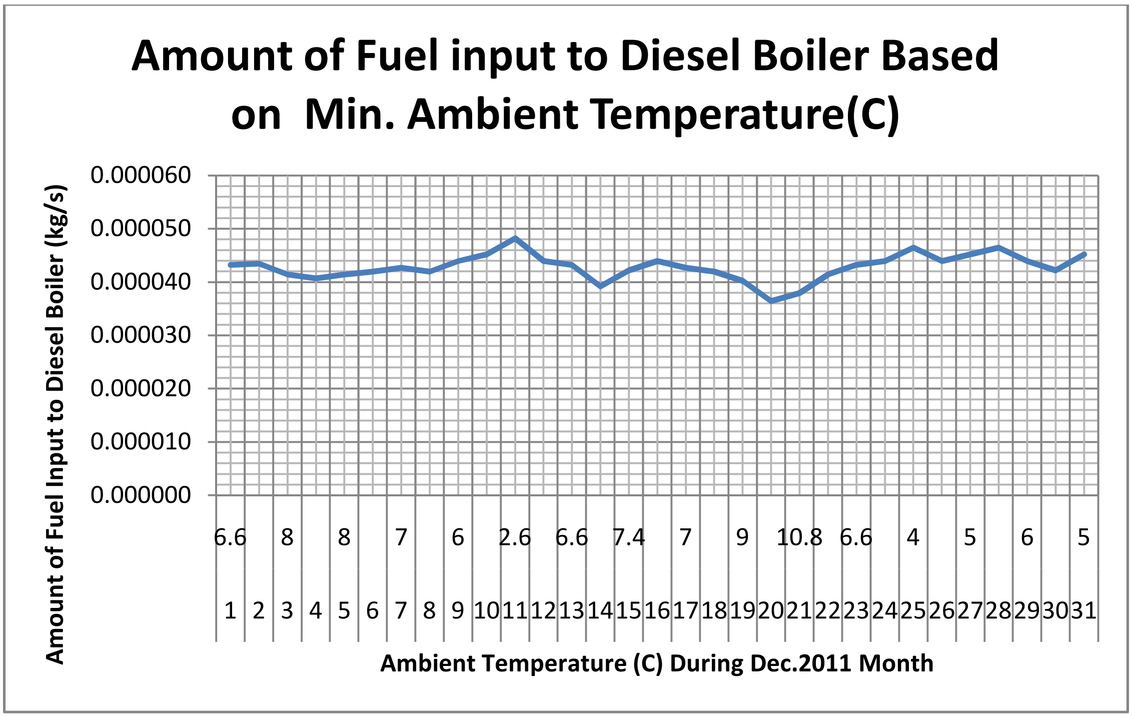


Figure (C-12) : The relation between the minimum ambient temperature & fuel consumption flow rate.

Infiltration air changes per hour occurring under average conditions in residences

Kind of room	*Single Glass, No Weatherstrip*	*Storm Sash or Weatherstripped*
No windows or exterior doors	0.5	0.3
Windows or exterior doors on one side	1	0.7
Windows or exterior doors on two sides	1.5	1
Windows or exterior doors on three sides	2	1.3
Entrance halls	2	1.3

Table (C-13): Infiltration Air Changes per hour occurring under average conditions in residences.

Appendix D: Interest Rates values based on 10% interest

10%	TABLE 15 Discrete Cash Flow: Compound Interest Factors							10%
	Single Payments		Uniform Series Payments				Arithmetic Gradients	
n	F/P Compound Amount	P/F Present Worth	A/F Sinking Fund	F/A Compound Amount	A/P Capital Recovery	P/A Present Worth	P/G Gradient Present Worth	A/G Gradient Uniform Series
1	1.1000	0.9091	1.00000	1.0000	1.10000	0.9091		
2	1.2100	0.8264	0.47619	2.1000	0.57619	1.7355	0.8264	0.4762
3	1.3310	0.7513	0.30211	3.3100	0.40211	2.4869	2.3291	0.9366
4	1.4641	0.6830	0.21547	4.6410	0.31547	3.1699	4.3781	1.3812
5	1.6105	0.6209	0.16380	6.1051	0.26380	3.7908	6.8618	1.8101
6	1.7716	0.5645	0.12961	7.7156	0.22961	4.3553	9.6842	2.2236
7	1.9487	0.5132	0.10541	9.4872	0.20541	4.8684	12.7631	2.6216
8	2.1436	0.4665	0.08744	11.4359	0.18744	5.3349	16.0287	3.0045
9	2.3579	0.4241	0.07364	13.5795	0.17364	5.7590	19.4215	3.3724
10	2.5937	0.3855	0.06275	15.9374	0.16275	6.1446	22.8913	3.7255
11	2.8531	0.3505	0.05396	18.5312	0.15396	6.4951	26.3963	4.0641
12	3.1384	0.3186	0.04676	21.3843	0.14676	6.8137	29.9012	4.3884
13	3.4523	0.2897	0.04078	24.5227	0.14078	7.1034	33.3772	4.6988
14	3.7975	0.2633	0.03575	27.9750	0.13575	7.3667	36.8005	4.9955
15	4.1772	0.2394	0.03147	31.7725	0.13147	7.6061	40.1520	5.2789
16	4.5950	0.2176	0.02782	35.9497	0.12782	7.8237	43.4164	5.5493
17	5.0545	0.1978	0.02466	40.5447	0.12466	8.0216	46.5819	5.8071
18	5.5599	0.1799	0.02193	45.5992	0.12193	8.2014	49.6395	6.0526
19	6.1159	0.1635	0.01955	51.1591	0.11955	8.3649	52.5827	6.2861
20	6.7275	0.1486	0.01746	57.2750	0.11746	8.5136	55.4069	6.5081
21	7.4002	0.1351	0.01562	64.0025	0.11562	8.6487	58.1095	6.7189
22	8.1403	0.1228	0.01401	71.4027	0.11401	8.7715	60.6893	6.9189
23	8.9543	0.1117	0.01257	79.5430	0.11257	8.8832	63.1462	7.1085
24	9.8497	0.1015	0.01130	88.4973	0.11130	8.9847	65.4813	7.2881
25	10.8347	0.0923	0.01017	98.3471	0.11017	9.0770	67.6964	7.4580
26	11.9182	0.0839	0.00916	109.1818	0.10916	9.1609	69.7940	7.6186
27	13.1100	0.0763	0.00826	121.0999	0.10826	9.2372	71.7773	7.7704
28	14.4210	0.0693	0.00745	134.2099	0.10745	9.3066	73.6495	7.9137
29	15.8631	0.0630	0.00673	148.6309	0.10673	9.3696	75.4146	8.0489
30	17.4494	0.0573	0.00608	164.4940	0.10608	9.4269	77.0766	8.1762
31	19.1943	0.0521	0.00550	181.9434	0.10550	9.4790	78.6395	8.2962
32	21.1138	0.0474	0.00497	201.1378	0.10497	9.5264	80.1078	8.4091
33	23.2252	0.0431	0.00450	222.2515	0.10450	9.5694	81.4856	8.5152
34	25.5477	0.0391	0.00407	245.4767	0.10407	9.6086	82.7773	8.6149
35	28.1024	0.0356	0.00369	271.0244	0.10369	9.6442	83.9872	8.7086
40	45.2593	0.0221	0.00226	442.5926	0.10226	9.7791	88.9525	9.0962
45	72.8905	0.0137	0.00139	718.9048	0.10139	9.8628	92.4544	9.3740
50	117.3909	0.0085	0.00086	1163.91	0.10086	9.9148	94.8889	9.5704
55	189.0591	0.0053	0.00053	1880.59	0.10053	9.9471	96.5619	9.7075
60	304.4816	0.0033	0.00033	3034.82	0.10033	9.9672	97.7010	9.8023
65	490.3707	0.0020	0.00020	4893.71	0.10020	9.9796	98.4705	9.8672
70	789.7470	0.0013	0.00013	7887.47	0.10013	9.9873	98.9870	9.9113
75	1271.90	0.0008	0.00008	12709	0.10008	9.9921	99.3317	9.9410
80	2048.40	0.0005	0.00005	20474	0.10005	9.9951	99.5606	9.9609
85	3298.97	0.0003	0.00003	32980	0.10003	9.9970	99.7120	9.9742
90	5313.02	0.0002	0.00002	53120	0.10002	9.9981	99.8118	9.9831
95	8556.68	0.0001	0.00001	85557	0.10001	9.9988	99.8773	9.9889

Table (D-1): interests rates values based on 10% interest.[15]

Appendix E: Tables of Calculations

Calculation Sheets for Heat Pump System According to the experimental data, for years 2011, 2012.

Calculation Sheets for Diesel Boiler System According to the experimental data, for years 2011, 2012.

Heat Pump Analysis during 2011 (Jan, Feb, Nov, Dec).

Heat Pump Analysis during 2011 (Jan, Feb, Nov, Dec).

Heat Pump

Appendix E1

Palestine Met. Office

T.Monthly Return

Station: Hebron

Month : January (1) Year : 2011

Day	Temp. Max.	Min.	Av.	R.H %	Rain (mm)	Sun Shine (Hour)	Evap. (mm)	wind AV.	Press. (mb)	Q (Heating Load) kW	Frow Rate(kg/s) QL/cp.(Ts-Tr)	COP1 Max,Carnot	Referred Equation. COP2=QHP/PI From Manf. Capacity Tables	P(kW), input QHL/COP2	W (kWh) P, input *time(h)	Cost (NIS)/Day w*cost per kWh	CO2 Emmission (kg)
1	11	7	8.2	97		1.7	3.8	10	899	6.110	0.122	9.00	3.13	1.95	23.42	15.22	17.33
2	12.8	7	9.2	85		6.8	3	8	898	6.700	0.134	9.00	3.13	2.14	25.68	16.69	19
3	14.8	7.6	10	83		5.9	3.5	6	895.8	7.300	0.146	9.16	3.18	2.30	27.58	17.93	20.41
4	11	7.8	8.3	91		2.2	3.8	8	896	6.700	0.134	9.21	3.19	2.10	25.19	16.38	18.64
5	11	6	8.2	86	0.6	6.5	2.4	8	898.1	6.700	0.134	8.75	3.06	2.19	26.29	17.09	19.46
6	11.6	7	8.5	94		2.2	3	6	901.2	7.300	0.146	9.00	3.13	2.33	27.98	18.18	20.7
7	13	6.6	8.7	88	8.1	7	3.1	6	900.9	7.300	0.146	8.90	3.10	2.35	28.24	18.36	20.9
8	7.4	5	5.3	99	7.1	0.8	2.1	10	898.8	6.110	0.122	8.51	2.99	2.05	24.55	15.96	18.17
9	10	5	6.8	95	2.2	5	2.8	8	901.3	6.700	0.134	8.51	2.99	2.24	26.92	17.50	19.92
10	10	5.5	7.8	89	1	4.5	2	10	902.4	6.110	0.122	8.63	3.02	2.02	24.26	15.77	17.95
11	14	6	9	89		5.3	4.8	6	901.6	7.300	0.146	8.75	3.06	2.39	28.65	18.62	21.2
12	12.8	6	9.3	67		7.6	1.5	10	898.1	6.110	0.122	8.75	3.06	2.00	23.98	15.59	17.74
13	12.4	5.6	8.8	58		7.3	3.2	14	893.5	4.920	0.098	8.65	3.03	1.62	19.49	12.67	14.42
14	14	5.8	8.5	70	1.8	6.9	3	6	892	7.300	0.146	8.70	3.04	2.40	28.78	18.71	21.3
15	7	4	5.9	98	12.2	0	1.6	8	894.2	6.700	0.134	8.29	2.92	2.30	27.56	17.91	20.39
16	10	4.5	7.2	94		1.8	3.5	10	898.6	6.110	0.122	8.40	2.95	2.07	24.84	16.15	18.38
17	12.4	7	9.5	65		5.4	3.1	8	893.7	6.700	0.134	9.00	3.13	2.14	25.68	16.69	19
18	11.5	7.8	8.1	73		0.2	3	18	894.7	3.730	0.074	9.21	3.19	1.17	14.03	9.12	10.38
19	13	4	8	76		6.6	3.4	8	898.2	6.700	0.134	8.29	2.92	2.30	27.56	17.91	20.39
20	15	5.5	9.3	60		7.7	4.5	6	899.4	7.300	0.146	8.63	3.02	2.42	28.99	18.84	21.45
21	12	5	8.4	60		7.4	3.8	12	900.2	5.510	0.110	8.51	2.99	1.84	22.14	14.39	16.38
22	14.5	5.6	9.7	62		6.2	4	8	900.5	6.700	0.134	8.65	3.03	2.21	26.54	17.25	19.64
23	16.5	7	11.1	61		7	4	4	901	7.890	0.157	9.00	3.13	2.52	30.24	19.65	22.38
24	15.6	7.5	10.3	66		7.5	4	6	899.4	7.300	0.146	9.13	3.17	2.30	27.65	17.97	20.46
25	14.8	7	9.5	71		2.5	3.3	6	895.5	7.300	0.146	9.00	3.13	2.33	27.98	18.18	20.7
26	10.5	6.4	8.4	85		5.5	3.9	8	895.9	6.700	0.134	8.85	3.09	2.17	26.04	16.93	19.27
27	16.5	7.5	11.2	59		6	4.6	12	897.3	5.510	0.110	9.13	3.17	1.74	20.87	13.56	15.44
28	16	7	11.8	64	1.8	7.1	4.7	8	899.5	6.700	0.134	9.00	3.13	2.14	25.68	16.69	19
29	16	9	12.1	68	6.6	5.4	3.2	12	893.6	5.510	0.110	9.55	3.28	1.68	20.14	13.09	14.9
30	10.5	8	7.5	100	36	0	1.4	16	891.5	4.330	0.086	9.26	3.21	1.35	16.20	10.53	11.99
31	7.5	5	6.1	100	30	0	1	16	892.5	4.330	0.086	8.51	2.99	1.45	17.40	11.31	12.87
Total					107.4		99										
Av.	12.4	6.3	8.7	79		4.7	3.2	9.1	897.5	6.4	0.127	8.83	3.08	2.07	24.84	16.15	18.38
Max.	16.5	9	12.1	100	36	7.7	4.8	18	902.4	7.89	0.157	9.55	3.28	2.40	28.83	18.74	21.34
Min.	7	4	5.3	58	0.6	0	1	4	891.5	3.73	0.074	8.29	2.92	1.28	15.34	9.97	11.35
Total															**770.521**	**500.838**	**570.160**

Palestine Met. Office																	
T.Monthly Return																	
Station: Hebron																	
Month : February (2)					Year : 2011								Referred Equation.				
	Temp.			R.H	Rain	Sun Shine	Evap.	WIND	Press.	Q (Heating Load)	Frow Rate(kg/s)	COP1	COP2=QHP/PI	P(kW), input	W (kWh)	Cost (NIS)/Day	CO2 Emmission
Day	Max.	Min.	Av.	%	(mm)	(Hour)	(mm)	AV	(mb)	(kW)	QL/cp.(Ts-Tr)	Max,Carnot	From Manf. Capacity Tables	QHL/COP2	P, input *time(h)	w*cost per kWh	(kg)
1	7	4.5	5.4	100	30.9	0.1	1	11	892.8	5.810	0.116	8.400	2.95	1.968	23.619	15.353	17.480
2	6.8	4	4.7	93		3	2.3	8	895.9	6.700	0.134	8.289	2.92	2.297	27.558	17.913	20.390
3	9.5	2.4	6.8	61		2	3.4	8	897.7	6.700	0.134	7.955	2.81	2.384	28.603	18.592	21.170
4	13	5.5	10.4	88	14	0	1	10	897.4	6.110	0.122	8.630	3.02	2.022	24.262	15.770	17.950
5	11	5	7.7	98		1	2.6	8	900.1	6.700	0.134	8.514	2.99	2.243	26.920	17.498	19.920
6	11	5	8.9	88	0.2	7.5	3.7	12	899.9	5.510	0.110	8.514	2.99	1.845	22.138	14.390	16.380
7	14.5	7	11	82	3.3	5.2	4	11	894.7	5.810	0.116	9.000	3.13	1.856	22.266	14.473	16.480
8	11	6.5	8.4	95	0.6	5.5	1.5	9	895.4	6.410	0.128	8.873	3.09	2.072	24.859	16.158	18.400
9	12	6	8.2	92	0.2	2.5	3	8	894.6	6.700	0.134	8.750	3.06	2.191	26.292	17.090	19.460
10	9	6	6.7	97	5.2	0.5	2.8	7	892.6	7.000	0.140	8.750	3.06	2.289	27.470	17.855	20.330
11	9	5.4	6.9	97	1	2.7	2.2	8	895.7	6.700	0.134	8.607	3.01	2.222	26.667	17.334	19.730
12	9	5	6.7	88		2	3	7	898.6	7.000	0.140	8.514	2.99	2.344	28.125	18.281	20.810
13	11.4	5	7.4	87		5.5	3	7	897.7	7.000	0.140	8.514	2.99	2.344	28.125	18.281	20.810
14	12.4	5.2	8.7	80		6.8	3.4	5	896.6	7.590	0.151	8.560	3.00	2.529	30.352	19.729	22.460
15	16	7.4	11	63	1.8	5.6	4.4	12	890.2	5.510	0.110	9.104	3.16	1.743	20.917	13.596	15.480
16	10	7	8.5	89	8.6	3.6	2.5	24	890.7	1.950	0.039	9.000	3.13	0.623	7.473	4.858	5.530
17	12.5	6.5	9	87		6.1	3.6	7	899.7	7.000	0.140	8.873	3.09	2.262	27.147	17.645	20.090
18	16	7	11.9	63		8.8	4.1	8	898.5	6.700	0.134	9.000	3.13	2.140	25.677	16.690	19.000
19	19	11	13	46		8.6	5.4	11	892.8	5.810	0.116	10.161	3.44	1.687	20.241	13.157	14.980
20	10	8.4	8.3	80	27.4	0	2.3	20	891.3	3.140	0.063	9.375	3.24	0.970	11.640	7.566	8.610
21	11.5	7	8	94		4.7	4.3	11	895.9	5.810	0.116	9.000	3.13	1.856	22.266	14.473	16.480
22	15.5	6.5	11.2	70		8.7	4.5	4	895.3	7.890	0.157	8.873	3.09	2.550	30.598	19.889	22.640
23	17	10	13.7	45		9.2	5	7	895.1	7.000	0.140	9.844	3.36	2.081	24.977	16.235	18.480
24	19	9	14.1	49		8.3	5.5	7	895.6	7.000	0.140	9.545	3.28	2.132	25.580	16.627	18.930
25	17.4	10.5	11.5	67		6	5.2	10	891.3	6.110	0.122	10.000	3.40	1.795	21.542	14.002	15.940
26	11	5.6	7.6	74		8.4	4	16	893.3	4.330	0.086	8.654	3.03	1.429	17.153	11.150	12.690
27	12.5	6.2	9	69		6.6	3	11	895.4	5.810	0.116	8.799	3.07	1.891	22.692	14.750	16.790
28	12	7	8.9	66		7.4	4.8	12	898.4	5.510	0.110	9.000	3.13	1.760	21.117	13.726	15.630
29																	
30																	
31																	
Total					93.2		95.5										
Av.	12.4	6.5	9.1	79		4.9	3.4	10.0	895.5	6.1	0.122	8.870	3.09	1.978	23.735	15.428	17.560
Max.	19	11	14.1	100	30.9	9.2	5.5	24	900.1	7.89	0.157	10.161	3.44	2.291	27.488	17.867	20.340
Min.	6.8	2.4	4.7	45	0.2	0	1	4	890.2	1.95	0.039	7.955	2.81	0.694	8.325	5.411	6.160
Total															**666.278**	**433.081**	**493.040**

Palestine Met. Office																	
T.Monthly Return																	
Station: Hebron																	
Month : November (11)					Year: 2011								Referred Equation.				
	Temp.			R.H	Rain	Sun Shine	Evap.	WIND	Press.	Q (Heating Load)	Frow Rate(kg/s)	COP1	COP2=QHP/PI	P(kW), input	W (kWh)	Cost (NIS)/Day	CO2 Emmission
Day	Max.	Min.	Av.	%	(mm)	(Hour)	(mm)	AV	(mb)	(kW)	QL/cp.(Ts-Tr)	Max,Carnot	From Manf. Capacity Tables	QHL/COP2	P, input *time(h)	w*cost per kWh	(kg)
1	21	10	13.9	59		8.2	3.4	8	899	6.700	0.134	9.844	3.36	1.992	23.906	15.539	17.690
2	20	10	14.5	57		8	4	9	897.7	6.410	0.128	9.844	3.36	1.906	22.872	14.867	16.920
3	17	11	13.4	88		7	2.5	10	893.9	6.110	0.122	10.161	3.44	1.774	21.286	13.836	15.750
4	12.4	11.8	11.4	99	1.2	0	0.7	10	893.7	6.110	0.122	10.430	3.51	1.740	20.883	13.574	15.450
5	15	9	10.7	87	2.4	2.8	4	11	897.7	5.810	0.116	9.545	3.28	1.769	21.232	13.801	15.710
6	14	9	11.2	89		6.6	2.7	14	900.7	4.920	0.098	9.545	3.28	1.498	17.979	11.686	13.300
7	16	9	12.2	83		8.2	2.3	8	901.7	6.700	0.134	9.545	3.28	2.040	24.484	15.915	18.120
8	17	9.4	12.5	82		6.6	3	8	902.3	6.700	0.134	9.663	3.32	2.021	24.251	15.763	17.950
9	18	9	13.1	47		8.1	3.7	6	900.4	7.300	0.146	9.545	3.28	2.223	26.676	17.340	19.740
10	21	11.6	16	30		6	4.4	5	896.9	7.590	0.151	10.362	3.49	2.172	26.066	16.943	19.290
11	24	12	23	27		7.2	4.7	9	898	6.410	0.128	10.500	3.53	1.817	21.804	14.172	16.130
12	21	14	16.8	39		7.8	5	12	897.9	5.510	0.110	11.250	3.70	1.489	17.867	11.614	13.220
13	20	9	14.3	51		7.5	4.5	8	896.1	6.700	0.134	9.545	3.28	2.040	24.484	15.915	18.120
14	16	11	12.5	80	3.8	3.9	3.8	11	893.2	5.810	0.116	10.161	3.44	1.687	20.241	13.157	14.980
15	12.8	7	9.3	75		7.8	4.4	19	894.2	3.430	0.068	9.000	3.13	1.095	13.145	8.544	9.730
16	12	6.6	9.3	83		3.4	3.1	18	897.4	3.730	0.074	8.898	3.10	1.203	14.431	9.380	10.680
17	13	9	10.5	94		5	4	9	898.3	6.410	0.128	9.545	3.28	1.952	23.424	15.226	17.330
18	12	8.4	9.5	97	3.5	0.5	1.5	7	897.7	7.000	0.140	9.375	3.24	2.162	25.949	16.867	19.200
19	10.4	7.8	8.1	100	13.9	1.6	1.2	10	896.2	6.110	0.122	9.211	3.19	1.915	22.975	14.934	17.000
20	11.5	6.4	8.1	98	0.8	1.5	3.2	8	897.6	6.700	0.134	8.848	3.09	2.170	26.045	16.929	19.270
21	12	7	8.3	96	17.3	3.7	2.2	6	899.6	7.300	0.146	9.000	3.13	2.331	27.977	18.185	20.700
22	15.6	6	10.7	75		7.2	4.3	6	902.4	7.300	0.146	8.750	3.06	2.387	28.647	18.621	21.200
23	16	8	11.3	68		7.5	3	6	902.1	7.300	0.146	9.265	3.21	2.277	27.320	17.758	20.220
24	13.6	8.5	10.3	94		3.8	2.7	7	900.1	7.000	0.140	9.403	3.24	2.157	25.887	16.826	19.160
25	12.5	7.4	9.3	84		6.5	3.6	9	899.1	6.410	0.128	9.104	3.16	2.028	24.334	15.817	18.010
26	13	4	7.6	72		7.7	3.9	6	899.2	7.300	0.146	8.289	2.92	2.502	30.026	19.517	22.220
27	12	4	7.6	72		7.5	3.4	7	898.5	7.000	0.140	8.289	2.92	2.399	28.792	18.715	21.310
28	13.5	4.6	8.6	43		7.6	3.5	5	899	7.590	0.151	8.422	2.96	2.565	30.783	20.009	22.780
29	13	5	8.8	37		7.8	3.8	7	901.8	7.000	0.140	8.514	2.99	2.344	28.125	18.281	20.810
30	14.4	6.8	9.6	40		7.8	3.2	8	899.7	6.700	0.134	8.949	3.12	2.150	25.799	16.769	19.090
31																	
Total					42.9		99.7										
Av.	15.3	8.4	11.4	72		5.8	3.3	8.9	898.4	6.4	0.128	9.378	3.24	1.987	23.850	15.502	17.650
Max.	24	14	23	100	17.3	8.2	5	19	902.4	7.59	0.151	11.250	3.70	2.051	24.612	15.998	18.210
Min.	10.4	4	7.6	27	0.8	0	0.7	5	893.2	3.43	0.068	8.289	2.92	1.176	14.108	9.170	10.440
Total															**717.690**	**466.499**	**531.080**

alestine Met. Office
T.Monthly Return
Station: Hebron
Year: 2011

Day	Temp.			R.H	Rain	Sun Shine	Evap.	WIND	Press.	Q (Heating Load)	Frow Rate(kg/s)	COP1	Referred Equation. COP2=QHP/PI	P(kW), input	W (kWh)	Cost (NIS)/Day	CO2 Emmission
	Max.	Min.	Av.	%	(mm)	(Hour)	(mm)	AV	(mb)	(kW)	QL/cp.(Ts-Tr)	Max,Carnot	From Manf. Capacity Tables	QHL/COP2	P, input *time(h)	w*cost per kWh	(kg)
1	15	6.6	9.9	36		7.5	4.2	7	900.2	7.000	0.140	8.898	3.10	2.257	27.082	17.604	20.040
2	17.5	6.4	10.8	39		7.6	4	7	900.5	7.000	0.140	8.848	3.09	2.268	27.211	17.687	20.140
3	16	8	11.7	37		7.5	2.8	8	902.1	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.550
4	14	8.6	10.9	27		7.9	2	9	903.2	6.410	0.128	9.431	3.25	1.971	23.649	15.372	17.500
5	18	8	11	22		8	4	8	900.9	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.550
6	16.6	7.6	10.8	40		7.8	2.5	5	901.5	7.590	0.151	9.157	3.18	2.390	28.676	18.640	21.220
7	15.8	7	10.6	52		8	3.8	6	901.2	7.300	0.146	9.000	3.13	2.331	27.977	18.185	20.700
8	12	7.6	9	89	10	5.7	3	14	898	4.920	0.098	9.157	3.18	1.549	18.589	12.083	13.760
9	10	6	7.8	95	0.3	1	1.7	16	899.2	4.330	0.086	8.750	3.06	1.416	16.992	11.045	12.570
10	11	5	6.9	81		7.4	2.8	11	902.3	5.810	0.116	8.514	2.99	1.945	23.344	15.173	17.270
11	13	2.6	7.3	68		7.7	3.2	9	904.2	6.410	0.128	7.995	2.82	2.270	27.239	17.705	20.160
12	17	6	11	43		7.8	3.6	7	902.8	7.000	0.140	8.750	3.06	2.289	27.470	17.855	20.330
13	18.6	6.6	12.4	45		7.4	4.1	7	901	7.000	0.140	8.898	3.10	2.257	27.082	17.604	20.040
14	16.4	9.8	11.1	72		0.6	3.1	7	899.1	7.000	0.140	9.783	3.35	2.091	25.096	16.313	18.570
15	13	7.4	8.9	87		7.5	1.3	12	899.6	5.510	0.110	9.104	3.16	1.743	20.917	13.596	15.480
16	12.4	6	8.8	90		7.2	2.2	9	900.5	6.410	0.128	8.750	3.06	2.096	25.154	16.350	18.610
17	15.8	7	10.6	83		7.5	1.8	7	899.7	7.000	0.140	9.000	3.13	2.236	26.827	17.437	19.850
18	17	7.6	11.7	55		7.8	4.2	12	900.7	5.510	0.110	9.157	3.18	1.735	20.818	13.532	15.410
19	18.4	9	14.4	34		7.6	4.7	12	901.2	5.510	0.110	9.545	3.28	1.678	20.135	13.088	14.900
20	23	12	15.5	40		7.6	2.1	6	899.6	7.300	0.146	10.500	3.53	2.069	24.831	16.140	18.370
21	15	10.8	11.1	97		0	2.2	6	897.8	7.300	0.146	10.096	3.43	2.129	25.554	16.610	18.910
22	16.6	8	11	79		7.5	0.4	4	897.3	7.890	0.157	9.265	3.21	2.461	29.528	19.193	21.850
23	13	6.6	9.5	67		7.7	3.7	10	895.5	6.110	0.122	8.898	3.10	1.970	23.639	15.365	17.490
24	10	6	8.1	72	10	6.5	3	23	894.3	2.250	0.045	8.750	3.06	0.736	8.830	5.739	6.530
25	7	4	6	99	40	0	1.5	18	898.1	3.730	0.074	8.289	2.92	1.279	15.342	9.972	11.350
26	10	6	7	98		2.2	3.5	11	902.1	5.810	0.116	8.750	3.06	1.900	22.800	14.820	16.870
27	11	5	6.9	83		7.7	4	12	904.6	5.510	0.110	8.514	2.99	1.845	22.138	14.390	16.380
28	14	4	7.9	71		7.5	4	9	902.5	6.410	0.128	8.289	2.92	2.197	26.366	17.138	19.510
29	15	6	10.1	58		7.7	4.5	5	899.7	7.590	0.151	8.750	3.06	2.482	29.785	19.360	22.040
30	13	7.4	10.7	55		0.1	5	9	896.8	6.410	0.128	9.104	3.16	2.028	24.334	15.817	18.010
31	11.6	5	7.8	86		5.2	3.5	8	896.8	6.700	0.134	8.514	2.99	2.243	26.920	17.498	19.920
Total					60.3		96.4										
Av.	14.4	6.9	9.9	65		6.1	3.1	9.5	900.1	6.3	0.125	8.972	3.12	2.005	24.061	15.640	17.800
Max.	23	12	15.5	99	40	8	5	23	904.6	7.89	0.157	10.500	3.53	2.236	26.838	17.445	19.860
Min.	7	2.6	6	22	0.3	0	0.4	4	894.3	2.25	0.045	7.995	2.82	0.797	9.561	6.215	7.080
Total															**744.472**	**483.907**	**550.880**

Electrical Energy (kWh)	Cost of Electrical Energy	CO2
770.521	500.838	570.160
666.278	433.081	493.040
717.690	466.499	531.080
744.472	483.907	550.880
2898.961	**1884.325**	**2145.160**

Heat Pump Analysis during 2012 (Jan, Feb, Nov, Dec).

Heat Pump

Appendix E2

Palestine Met. Office

T.Monthly Return

Station: Hebron

Month : January (1) Year: 2012

Day	Temp. Max.	Min.	Av.	Q (Heating Load) (kW)	Frow Rate(kg/s) QL/cp.(Ts-Tr)	COP1 Max,Carnot	COP2=QHP/PI From Manf. Capacity Tables	P(kW), input QHL/COP2	W (kWh) P, input *time(h)	Cost (NIS)/Day w*cost per kWh	CO2 Emmission (kg)
1	28	1	19	8.780	0.175	7.683	2.72	3.226	38.709	25.161	28.64
2	20	2	10	8.490	0.169	7.875	2.79	3.048	36.581	23.778	27.07
3	12	3	7	8.190	0.163	8.077	2.85	2.873	34.481	22.413	25.52
4	12	4	8	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
5	12	4	7	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
6	24	6	13	7.300	0.146	8.750	3.06	2.387	28.647	18.621	21.2
7	12	0	8	9.080	0.181	7.500	2.66	3.413	40.951	26.618	30.3
8	36	6	22	7.300	0.146	8.750	3.06	2.387	28.647	18.621	21.2
9	18	6	12	7.300	0.146	8.750	3.06	2.387	28.647	18.621	21.2
10	10	4	6	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
11	32	8	20	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
12	28	10	17	6.110	0.122	9.844	3.36	1.817	21.801	14.171	16.13
13	36	13	23	5.220	0.104	10.862	3.61	1.445	17.336	11.269	12.83
14	14	8	12	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
15	18	0	8	9.080	0.181	7.500	2.66	3.413	40.951	26.618	30.3
16	12	4	8	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
17	18	4	10	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
18	14	4	9	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
19	16	6	12	7.300	0.146	8.750	3.06	2.387	28.647	18.621	21.2
20	12	4	9	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
21	8	4	6	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
22	30	8	15	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
23	16	4	9	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
24	10	4	6	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
25	12	4	9	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
26	24	6	13	7.300	0.146	8.750	3.06	2.387	28.647	18.621	21.2
27	50	16	31	4.330	0.086	12.115	3.88	1.116	13.387	8.701	9.91
28	20	6	12	7.300	0.146	8.750	3.06	2.387	28.647	18.621	21.2
29	8	4	5	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
30	20	4	12	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
31	40	6	16	7.300	0.146	8.750	3.06	2.387	28.647	18.621	21.2
Av.	20.065	5.258	11.911	7.518	0.150	8.654	3.00	2.532	30.382	19.748	22.48
Max.	50.000	16.000	30.500	9.080	0.181	12.115	3.88	3.413	40.951	26.618	30.3
Min.	8.000	0.000	5.000	4.330	0.086	7.500	2.66	1.116	13.387	8.701	9.91
Total									**941.839**	**612.196**	**697.010**

Palestine Met. Office

T.Monthly Return

Station: Hebron

Month : February (2) **Year: 2012**

Day	Temp. Max.	Min.	Av.	Q (Heating Load) (kW)	Frow Rate(kg/s) QL/cp.(Ts-Tr)	COP1 Max,Carnot	COP2=QHP/PI From Manf. Capacity Tables	P(kW), input QHL/COP2	W (kWh) P, input *time(h)	Cost (NIS)/Day w*cost per kWh	CO2 Emmission (kg)
1	4.8	3	15.3	8.190	0.163	8.077	2.85	2.873	34.481	22.413	25.52
2	7	3	8.5	8.190	0.163	8.077	2.85	2.873	34.481	22.413	25.52
3	12	3	11.3	8.190	0.163	8.077	2.85	2.873	34.481	22.413	25.52
4	12	5	13.5	7.590	0.151	8.514	2.99	2.541	30.496	19.822	22.57
5	13.6	5	10.5	7.590	0.151	8.514	2.99	2.541	30.496	19.822	22.57
6	15	6.8	9.0	7.060	0.141	8.949	3.12	2.265	27.185	17.671	20.12
7	13	9	12.0	6.410	0.128	9.545	3.28	1.952	23.424	15.226	17.33
8	8	1	8.5	8.780	0.175	7.683	2.72	3.226	38.709	25.161	28.64
9	10	3	7.5	8.190	0.163	8.077	2.85	2.873	34.481	22.413	25.52
10	7	3.8	13.0	7.950	0.158	8.246	2.90	2.738	32.853	21.355	24.31
11	11	3	7.8	8.190	0.163	8.077	2.85	2.873	34.481	22.413	25.52
12	13.6	5.5	10.8	7.450	0.149	8.630	3.02	2.465	29.583	19.229	21.89
13	17.6	6.6	10.3	7.120	0.142	8.898	3.10	2.296	27.547	17.905	20.38
14	17	8	9.3	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
15	15	12	10.0	5.510	0.110	10.500	3.53	1.562	18.742	12.183	13.87
16	6	4	13.5	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
17	9	3	26.0	8.190	0.163	8.077	2.85	2.873	34.481	22.413	25.52
18	3	0	18.0	9.080	0.181	7.500	2.66	3.413	40.951	26.618	30.3
19	5	-1	2.2	9.380	0.187	7.326	2.60	3.605	43.266	28.123	32.02
20	8	5	9.8	7.590	0.151	8.514	2.99	2.541	30.496	19.822	22.57
21	11.4	1.2	14.5	8.720	0.174	7.721	2.73	3.189	38.269	24.875	28.32
22	14	3.4	11.0	8.070	0.161	8.161	2.88	2.805	33.662	21.880	24.91
23	16	6.0	5.3	7.300	0.146	8.750	3.06	2.387	28.647	18.621	21.2
24	13.6	8	12.0	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
25	10	4.6	10.5	7.710	0.154	8.422	2.96	2.606	31.270	20.326	23.14
26	11	5.4	7.0	7.480	0.149	8.607	3.01	2.481	29.772	19.352	22.03
27	12	6	7.8	7.300	0.146	8.750	3.06	2.387	28.647	18.621	21.2
28	15.6	8	13.5	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
29	8	3.4	31.5	8.070	0.161	8.161	2.88	2.805	33.662	21.880	24.91
Av.	11.007	4.645	11.705	7.700	0.154	8.480	2.96	2.621	31.457	20.447	23.28
Max.	17.600	12.000	31.500	9.380	0.187	10.500	3.53	3.605	43.266	28.123	32.02
Min.	3.000	-1.000	2.200	5.510	0.110	7.326	2.60	1.562	18.742	12.183	13.87
Total									912.239	592.955	675.070

Palestine Met. Office											
T.Monthly Return											
Station: Hebron											
Month : November (11)						Year: 2012					
	Temp.			Q (Heating Load)	Frow Rate(kg/s)	COP1	COP2=QHP/PI	P(kW), input	W (kWh)	Cost (NIS)/Day	CO2 Emmission
Day	Max.	Min.	Av.	(kW)	QL/cp.(Ts-Tr)	Max,Carnot	From Manf. Capacity Tables	QHL/COP2	P, input *time(h)	w*cost per kWh	(kg)
1	29.5	20.4	23.4	3.020	0.060	14.583	4.31	0.701	8.412	5.468	6.23
2	29	20.5	23.1	2.990	0.060	14.651	4.32	0.692	8.309	5.401	6.15
3	27	19	22.3	3.430	0.068	13.696	4.17	0.823	9.875	6.419	7.31
4	26.5	17.8	21.1	3.790	0.076	13.017	4.05	0.936	11.226	7.297	8.31
5	26.4	19	21.4	3.430	0.068	13.696	4.17	0.823	9.875	6.419	7.31
6	26	16.6	21.1	4.150	0.083	12.402	3.94	1.054	12.648	8.221	9.36
7	25	16	19.6	4.330	0.086	12.115	3.88	1.116	13.387	8.701	9.91
8	25	16.6	18.8	4.150	0.083	12.402	3.94	1.054	12.648	8.221	9.36
9	17	14	14.7	4.920	0.098	11.250	3.70	1.329	15.954	10.370	11.81
10	16	10.4	12.8	5.990	0.119	9.968	3.40	1.764	21.170	13.760	15.67
11	14.6	11	11.4	5.810	0.116	10.161	3.44	1.687	20.241	13.157	14.98
12	12.4	9.4	10.6	6.290	0.125	9.663	3.32	1.897	22.767	14.799	16.85
13	15.4	9.4	11.8	6.290	0.125	9.663	3.32	1.897	22.767	14.799	16.85
14	17.4	10.4	13.7	5.990	0.119	9.968	3.40	1.764	21.170	13.760	15.67
15	18	11.8	14.2	5.570	0.111	10.430	3.51	1.586	19.037	12.374	14.09
16	20	11	14.8	5.810	0.116	10.161	3.44	1.687	20.241	13.157	14.98
17	21	12	16.3	5.510	0.110	10.500	3.53	1.562	18.742	12.183	13.87
18	21	14.4	16.5	4.800	0.096	11.413	3.74	1.285	15.417	10.021	11.41
19	17	12	13.8	5.510	0.110	10.500	3.53	1.562	18.742	12.183	13.87
20	18.4	11	14.2	5.810	0.116	10.161	3.44	1.687	20.241	13.157	14.98
21	20.4	11.4	15.3	5.690	0.113	10.294	3.48	1.636	19.634	12.762	14.53
22	19	13.0	15.0	5.220	0.104	10.862	3.61	1.445	17.336	11.269	12.83
23	13	11.0	11.4	5.810	0.116	10.161	3.44	1.687	20.241	13.157	14.98
24	14	10	11.5	6.110	0.122	9.844	3.36	1.817	21.801	14.171	16.13
25	14.4	10	10.9	6.110	0.122	9.844	3.36	1.817	21.801	14.171	16.13
26	16	9	12.1	6.410	0.128	9.545	3.28	1.952	23.424	15.226	17.33
27	16	9	12.2	6.410	0.128	9.545	3.28	1.952	23.424	15.226	17.33
28	17.4	10	13.3	6.110	0.122	9.844	3.36	1.817	21.801	14.171	16.13
29	18.6	10	13.7	6.110	0.122	9.844	3.36	1.817	21.801	14.171	16.13
30	22	12	15.6	5.510	0.110	10.500	3.53	1.562	18.742	12.183	13.87
Av.	19.780	12.937	15.542	5.236	0.104	11.023	3.61	1.480	17.763	11.546	13.14
Max.	29.500	20.500	23.350	6.410	0.128	14.651	4.32	1.952	23.424	15.226	17.33
Min.	12.400	9.000	10.600	2.990	0.060	9.545	3.28	0.692	8.309	5.401	6.15
Total									532.879	346.371	394.360

Palestine Met. Office T.Monthly Return Station: Hebron											
Month : December (12)							Year: 2012				
	Temp.			Q (Heating Load)	Flow Rate(kg/s)	COP1	COP2=QHP/PI	P(kW), input	W (kWh)	Cost (NIS)/Day	CO2 Emmission
Day	Max.	Min.	Av.	(kW)	QL/cp.(Ts-Tr)	Max,Carnot	From Manf. Capacity Tables	QHL/COP2	P, input *time(h)	w*cost per kWh	(kg)
1	21	12	15.9	5.510	0.110	10.500	3.53	1.562	18.742	12.183	13.87
2	22	13.5	16.7	5.070	0.101	11.053	3.66	1.387	16.638	10.815	12.31
3	23.6	12	16.6	5.510	0.110	10.500	3.53	1.562	18.742	12.183	13.87
4	17.4	12.4	13.4	5.400	0.108	10.642	3.56	1.516	18.193	11.826	13.46
5	10.6	8.6	9.1	6.520	0.130	9.431	3.25	2.005	24.054	15.635	17.8
6	12	7.6	9.6	6.820	0.136	9.157	3.18	2.147	25.767	16.749	19.07
7	13.6	8	10.4	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
8	11.6	8	9.7	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
9	18	8.8	12.2	6.460	0.129	9.488	3.27	1.977	23.720	15.418	17.55
10	12	8	10.2	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
11	9	4	6.8	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
12	12.6	7	9.7	7.000	0.140	9.000	3.13	2.236	26.827	17.437	19.85
13	9.5	7.4	8.1	6.880	0.137	9.104	3.16	2.176	26.118	16.977	19.33
14	11	6.5	8.9	7.150	0.143	8.873	3.09	2.311	27.728	18.023	20.52
15	13	7.0	8.9	7.000	0.140	9.000	3.13	2.236	26.827	17.437	19.85
16	11	5.4	8.2	7.480	0.149	8.607	3.01	2.481	29.772	19.352	22.03
17	12	6.5	9.5	7.150	0.143	8.873	3.09	2.311	27.728	18.023	20.52
18	16	8	11.0	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
19	14	8	11.0	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
20	9	7.6	8.1	6.820	0.136	9.157	3.18	2.147	25.767	16.749	19.07
21	7.4	4	5.9	7.890	0.157	8.289	2.92	2.704	32.453	21.095	24.02
22	11.5	5.6	7.7	7.420	0.148	8.654	3.03	2.450	29.394	19.106	21.75
23	14	5.0	10.4	7.590	0.151	8.514	2.99	2.541	30.496	19.822	22.57
24	15	8	10.8	6.700	0.134	9.265	3.21	2.090	25.074	16.298	18.55
25	10.6	7.6	8.9	6.820	0.136	9.157	3.18	2.147	25.767	16.749	19.07
26	11.8	8.4	9.2	6.580	0.131	9.375	3.24	2.033	24.392	15.855	18.05
27	14	7.6	9.7	6.820	0.136	9.157	3.18	2.147	25.767	16.749	19.07
28	15.6	7	10.9	7.000	0.140	9.000	3.13	2.236	26.827	17.437	19.85
29	15.6	7.6	10.6	6.820	0.136	9.157	3.18	2.147	25.767	16.749	19.07
30	15	7.6	10.1	6.820	0.136	9.157	3.18	2.147	25.767	16.749	19.07
31	14.5	7	10.2								
Av.	13.674	7.797	10.263	6.754	0.135	9.257	3.19	2.128	25.538	16.600	18.9
Max.	23.600	13.500	16.651	7.890	0.157	11.053	3.66	2.704	32.453	21.095	24.02
Min.	7.400	4.000	5.900	5.070	0.101	8.289	2.92	1.387	16.638	10.815	12.31
Total									766.154	498.000	566.940

Electrical Energy (kWh)	Cost of Electrical Energy	CO2
941.839	612.196	697.010
912.239	592.955	675.070
532.879	346.371	394.360
766.154	498.000	566.940
3153.111	2049.522	2333.380

Boiler Analysis during 2012 (Jan, Feb, Nov, Dec).

Boiler

Appendix E3

Palestine Met. Office T.Monthly Return Station: Hebron Month : January (1) Year : 2011																
	Temp.			R.H	Rain	Sun Shine	Evap.	wind	Press.	Q (Heating Load)	Water Flow Rate(kg/s)	Fuel Flow Rate (kg/s)	Diesel Consumption/Day	Conversion Ltr Diesel to kWh	Cost (NIS)/Day	CO2 Emmission
Day	Max.	Min.	Av.	%	(mm)	(Hour)	(mm)	AV.	(mb)	(kW)	QL/Cp.(Ts-Tr)	mf=QHL/(ζ*Heating Value)	Litre/Day	kWh	w*cost per kWh	(kg)
1	11	7	8.2	97		1.7	3.8	10	899	6.110	0.122	0.00017	8.820	80.26	52.92000	18.33
2	12.8	7	9.2	85		6.8	3	8	898	6.700	0.134	0.00019	9.670	88.00	58.02000	20.10
3	14.8	7.6	10	83		5.9	3.5	6	895.8	7.300	0.146	0.00020	10.540	95.91	63.24000	21.90
4	11	7.8	8.3	91		2.2	3.8	8	896	6.700	0.134	0.00019	9.670	88.00	58.02000	20.10
5	11	6	8.2	86	0.6	6.5	2.4	8	898.1	6.700	0.134	0.00019	9.670	88.00	58.02000	20.10
6	11.6	7	8.5	94		2.2	3	6	901.2	7.300	0.146	0.00020	10.540	95.91	63.24000	21.90
7	13	6.6	8.7	88	8.1	7	3.1	6	900.9	7.300	0.146	0.00020	10.540	95.91	63.24000	21.90
8	7.4	5	5.3	99	7.1	0.8	2.1	10	898.8	6.110	0.122	0.00017	8.820	80.26	52.92000	18.33
9	10	5	6.8	95	2.2	5	2.8	8	901.3	6.700	0.134	0.00019	9.670	88.00	58.02000	20.10
10	10	5.5	7.8	89	1	4.5	2	10	902.4	6.110	0.122	0.00017	8.820	80.26	52.92000	18.33
11	14	6	9	89		5.3	4.8	6	901.6	7.300	0.146	0.00020	10.540	95.91	63.24000	21.90
12	12.8	6	9.3	67		7.6	1.5	10	898.1	6.110	0.122	0.00017	8.820	80.26	52.92000	18.33
13	12.4	5.6	8.8	58		7.3	3.2	14	893.5	4.920	0.098	0.00014	7.100	64.61	42.60000	14.76
14	14	5.8	8.5	70	1.8	6.9	3	6	892	7.300	0.146	0.00020	10.540	95.91	63.24000	21.90
15	7	4	5.9	98	12.2	0	1.6	8	894.2	6.700	0.134	0.00019	9.670	88.00	58.02000	20.10
16	10	4.5	7.2	94		1.8	3.5	10	898.6	6.110	0.122	0.00017	8.820	80.26	52.92000	18.33
17	12.4	7	9.5	65		5.4	3.1	8	893.7	6.700	0.134	0.00019	9.670	88.00	58.02000	20.10
18	11.5	7.8	8.1	73		0.2	3	18	894.7	3.730	0.074	0.00010	5.380	48.96	32.28000	11.19
19	13	4	8	76		6.6	3.4	8	898.2	6.700	0.134	0.00019	9.670	88.00	58.02000	20.10
20	15	5.5	9.3	60		7.7	4.5	6	899.4	7.300	0.146	0.00020	10.540	95.91	63.24000	21.90
21	12	5	8.4	60		7.4	3.8	12	900.2	5.510	0.110	0.00015	7.950	72.35	47.70000	16.53
22	14.5	5.6	9.7	62		6.2	4	8	900.5	6.700	0.134	0.00019	9.670	88.00	58.02000	20.10
23	16.5	7	11.1	61		7	4	4	901	7.890	0.157	0.00022	11.390	103.65	68.34000	23.67
24	15.6	7.5	10.3	66		7.5	4	6	899.4	7.300	0.146	0.00020	10.540	95.91	63.24000	21.90
25	14.8	7	9.5	71		2.5	3.3	6	895.5	7.300	0.146	0.00020	10.540	95.91	63.24000	21.90
26	10.5	6.4	8.4	85		5.5	3.9	8	895.9	6.700	0.134	0.00019	9.670	88.00	58.02000	20.10
27	16.5	7.5	11.2	59		6	4.6	12	897.3	5.510	0.110	0.00015	7.950	72.35	47.70000	16.53
28	16	7	11.8	64	1.8	7.1	4.7	8	899.5	6.700	0.134	0.00019	9.670	88.00	58.02000	20.10
29	16	9	12.1	68	6.6	5.4	3.2	12	893.6	5.510	0.110	0.00015	7.950	72.35	47.70000	16.53
30	10.5	8	7.5	100	36	0	1.4	16	891.5	4.330	0.086	0.00012	6.250	56.88	37.50000	12.99
31	7.5	5	6.1	100	30	0	1	16	892.5	4.330	0.086	0.00012	6.250	56.88	37.50000	12.99
Total					107.4		99									
Av.	12.4	6.3	8.7	79		4.7	3.2	9.1	897.5	6.4	0.127	0.00018	9.20514	83.77	55.23083	19.13
Max.	16.5	9	12.1	100	36	7.7	4.8	18	902.4	7.89	0.157	0.00022	11.38954	103.64	68.33725	23.67
Min.	7	4	5.3	58	0.6	0	1	4	891.5	3.73	0.074	0.00010	5.38441	49.00	32.30646	11.19
Total													**285.34000**	**2596.59**	**1712.040**	**593.040**

Palestine Met. Office

T.Monthly Return

Station: Hebron

Month : February (2) Year : 2011

Day	Temp. Max.	Min.	Av.	R.H %	Rain (mm)	Sun Shine (Hour)	Evap. (mm)	WIND AV	Press. (mb)	Q (Heating Load) (kW)	Water Flow Rate(kg/s) QL/Cp.(Ts-Tr)	Fuel Flow Rate (kg/s) mf=QHL/(ζ*Heating Value)	Diesel Consumption/Day Litre/Day	Conversion Ltr Diesel to kWh kWh	Cost (NIS)/Day w*cost per kWh	CO2 Emmission (kg)
1	7	4.5	5.4	100	30.9	0.1	1	11	892.8	5.810	0.116	0.000162	8.387	76.32	50.322	17.430
2	6.8	4	4.7	93		3	2.3	8	895.9	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
3	9.5	2.4	6.8	61		2	3.4	8	897.7	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
4	13	5.5	10.4	88	14	0	1	10	897.4	6.110	0.122	0.000170	8.820	80.26	52.920	18.330
5	11	5	7.7	98		1	2.6	8	900.1	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
6	11	5	8.9	88	0.2	7.5	3.7	12	899.9	5.510	0.110	0.000154	7.954	72.38	47.724	16.530
7	14.5	7	11	82	3.3	5.2	4	11	894.7	5.810	0.116	0.000162	8.387	76.32	50.322	17.430
8	11	6.5	8.4	95	0.6	5.5	1.5	9	895.4	6.410	0.128	0.000179	9.253	84.20	55.518	19.230
9	12	6	8.2	92	0.2	2.5	3	8	894.6	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
10	9	6	6.7	97	5.2	0.5	2.8	7	892.6	7.000	0.140	0.000195	10.105	91.96	60.630	21.000
11	9	5.4	6.9	97	1	2.7	2.2	8	895.7	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
12	9	5	6.7	88		2	3	7	898.6	7.000	0.140	0.000195	10.105	91.96	60.630	21.000
13	11.4	5	7.4	87		5.5	3	7	897.7	7.000	0.140	0.000195	10.105	91.96	60.630	21.000
14	12.4	5.2	8.7	80		6.8	3.4	5	896.6	7.590	0.151	0.000212	10.956	99.70	65.736	22.770
15	16	7.4	11	63	1.8	5.6	4.4	12	890.2	5.510	0.110	0.000154	7.954	72.38	47.724	16.530
16	10	7	8.5	89	8.6	3.6	2.5	24	890.7	1.950	0.039	0.000054	2.815	25.62	16.890	5.850
17	12.5	6.5	9	87		6.1	3.6	7	899.7	7.000	0.140	0.000195	10.105	91.96	60.630	21.000
18	16	7	11.9	63		8.8	4.1	8	898.5	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
19	19	11	13	46		8.6	5.4	11	892.8	5.810	0.116	0.000162	8.387	76.32	50.322	17.430
20	10	8.4	8.3	80	27.4	0	2.3	20	891.3	3.140	0.063	0.000088	4.533	41.25	27.198	9.420
21	11.5	7	8	94		4.7	4.3	11	895.9	5.810	0.116	0.000162	8.387	76.32	50.322	17.430
22	15.5	6.5	11.2	70		8.7	4.5	4	895.3	7.890	0.157	0.000220	11.390	103.65	68.340	23.670
23	17	10	13.7	45		9.2	5	7	895.1	7.000	0.140	0.000195	10.105	91.96	60.630	21.000
24	19	9	14.1	49		8.3	5.5	7	895.6	7.000	0.140	0.000195	10.105	91.96	60.630	21.000
25	17.4	10.5	11.5	67		6	5.2	10	891.3	6.110	0.122	0.000170	8.820	80.26	52.920	18.330
26	11	5.6	7.6	74		8.4	4	16	893.3	4.330	0.086	0.000121	6.251	56.88	37.506	12.990
27	12.5	6.2	9	69		6.6	3	11	895.4	5.810	0.116	0.000162	8.387	76.32	50.322	17.430
28	12	7	8.9	66		7.4	4.8	12	898.4	5.510	0.110	0.000154	7.954	72.38	47.724	16.530
29																
30																
31																
Total					93.2		95.5									
Av.	12.4	6.5	9.1	79		4.9	3.4	10.0	895.5	6.1	0.122	0.000171	8.832	80.37	52.991	18.355
Max.	19	11	14.1	100	30.9	9.2	5.5	24	900.1	7.89	0.157	0.000220	11.390	103.64	68.337	23.670
Min.	6.8	2.4	4.7	45	0.2	0	1	4	890.2	1.95	0.039	0.000054	2.815	25.62	16.889	5.850
Total													**247.297**	**2250.40**	**1483.78**	**513.930**

Palestine Met. Office

T.Monthly Return

Station: Hebron

Month : November (11) Year: 2011

	Temp.			R.H	Rain	Sun Shine	Evap.	WIND	Press.	Q (Heating Load)	Water Flow Rate(kg/s)	Fuel Flow Rate (kg/s)	Diesel Consumption/Day	Conversion Ltr Diesel to kWh	Cost (NIS)/Day	CO2 Emmission
Day	Max.	Min.	Av.	%	(mm)	(Hour)	(mm)	AV	(mb)	(kW)	QL/Cp.(Ts-Tr)	mf=QHL/(ζ*Heating Value)	Litre/Day	kWh	w*cost per kWh	(kg)
1	21	10	13.9	59		8.2	3.4	8	899	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
2	20	10	14.5	57		8	4	9	897.7	6.410	0.128	0.000179	9.253	84.20	55.518	19.230
3	17	11	13.4	88		7	2.5	10	893.9	6.110	0.122	0.000170	8.820	80.26	52.920	18.330
4	12.4	11.8	11.4	99	1.2	0	0.7	10	893.7	6.110	0.122	0.000170	8.820	80.26	52.920	18.330
5	15	9	10.7	87	2.4	2.8	4	11	897.7	5.810	0.116	0.000162	8.387	76.32	50.322	17.430
6	14	9	11.2	89		6.6	2.7	14	900.7	4.920	0.098	0.000137	7.102	64.63	42.612	14.760
7	16	9	12.2	83		8.2	2.3	8	901.7	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
8	17	9.4	12.5	82		6.6	3	8	902.3	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
9	18	9	13.1	47		8.1	3.7	6	900.4	7.300	0.146	0.000204	10.538	95.90	63.228	21.900
10	21	11.6	16	30		6	4.4	5	896.9	7.590	0.151	0.000212	10.956	99.70	65.736	22.770
11	24	12	23	27		7.2	4.7	9	898	6.410	0.128	0.000179	9.253	84.20	55.518	19.230
12	21	14	16.8	39		7.8	5	12	897.9	5.510	0.110	0.000154	7.954	72.38	47.724	16.530
13	20	9	14.3	51		7.5	4.5	8	896.1	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
14	16	11	12.5	80	3.8	3.9	3.8	11	893.2	5.810	0.116	0.000162	8.387	76.32	50.322	17.430
15	12.8	7	9.3	75		7.8	4.4	19	894.2	3.430	0.068	0.000096	4.951	45.05	29.706	10.290
16	12	6.6	9.3	83		3.4	3.1	18	897.4	3.730	0.074	0.000104	5.384	48.99	32.304	11.190
17	13	9	10.5	94		5	4	9	898.3	6.410	0.128	0.000179	9.253	84.20	55.518	19.230
18	12	8.4	9.5	97	3.5	0.5	1.5	7	897.7	7.000	0.140	0.000195	10.105	91.96	60.630	21.000
19	10.4	7.8	8.1	100	13.9	1.6	1.2	10	896.2	6.110	0.122	0.000170	8.820	80.26	52.920	18.330
20	11.5	6.4	8.1	98	0.8	1.5	3.2	8	897.6	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
21	12	7	8.3	96	17.3	3.7	2.2	6	899.6	7.300	0.146	0.000204	10.538	95.90	63.228	21.900
22	15.6	6	10.7	75		7.2	4.3	6	902.4	7.300	0.146	0.000204	10.538	95.90	63.228	21.900
23	16	8	11.3	68		7.5	3	6	902.1	7.300	0.146	0.000204	10.538	95.90	63.228	21.900
24	13.6	8.5	10.3	94		3.8	2.7	7	900.1	7.000	0.140	0.000195	10.105	91.96	60.630	21.000
25	12.5	7.4	9.3	84		6.5	3.6	9	899.1	6.410	0.128	0.000179	9.253	84.20	55.518	19.230
26	13	4	7.6	72		7.7	3.9	6	899.2	7.300	0.146	0.000204	10.538	95.90	63.228	21.900
27	12	4	7.6	72		7.5	3.4	7	898.5	7.000	0.140	0.000195	10.105	91.96	60.630	21.000
28	13.5	4.6	8.6	43		7.6	3.5	5	899	7.590	0.151	0.000212	10.956	99.70	65.736	22.770
29	13	5	8.8	37		7.8	3.8	7	901.8	7.000	0.140	0.000195	10.105	91.96	60.630	21.000
30	14.4	6.8	9.6	40		7.8	3.2	8	899.7	6.700	0.134	0.000187	9.672	88.02	58.032	20.100
31																
Total					42.9		99.7									
Av.	15.3	8.4	11.4	72		5.8	3.3	8.9	898.4	6.4	0.128	0.000180	9.290	84.54	55.738	19.306
Max.	24	14	23	100	17.3	8.2	5	19	902.4	7.59	0.151	0.000212	10.956	99.70	65.739	22.770
Min.	10.4	4	7.6	27	0.8	0	0.7	5	893.2	3.43	0.068	0.000096	4.951	45.06	29.708	10.290
Total													**278.691**	**2536.09**	**1672.146**	**579.180**

Palestine Met. Office
T.Monthly Return
Station: Hebron

Month : December (12) Year: 2011

Day	Temp. Max.	Min.	Av.	R.H %	Rain (mm)	Sun Shine (Hour)	Evap. (mm)	WIND AV	Press. (mb)	Q (Heating Load) (kW)	Water Flow Rate(kg/s) QL/Cp.(Ts-Tr)	Fuel Flow Rate (kg/s) mf=QHL/(ζ*Heating Value)	Diesel Consumption/Day Litre/Day	Conversion Ltr Diesel to kWh kWh	Cost (NIS)/Day w*cost per kWh	CO2 Emmission (kg)
1	15	6.6	9.9	36		7.5	4.2	7	900.2	7.000	0.140	0.000195	10.100	91.91	60.600	21.000
2	17.5	6.4	10.8	39		7.6	4	7	900.5	7.000	0.140	0.000195	10.100	91.91	60.600	21.000
3	16	8	11.7	37		7.5	2.8	8	902.1	6.700	0.134	0.000187	9.670	88.00	58.020	20.100
4	14	8.6	10.9	27		7.9	2	9	903.2	6.410	0.128	0.000179	9.250	84.18	55.500	19.230
5	18	8	11	22		8	4	8	900.9	6.700	0.134	0.000187	9.670	88.00	58.020	20.100
6	16.6	7.6	10.8	40		7.8	2.5	5	901.5	7.590	0.151	0.000212	10.960	99.74	65.760	22.770
7	15.8	7	10.6	52		8	3.8	6	901.2	7.300	0.146	0.000204	10.540	95.91	63.240	21.900
8	12	7.6	9	89	10	5.7	3	14	898	4.920	0.098	0.000137	7.100	64.61	42.600	14.760
9	10	6	7.8	95	0.3	1	1.7	16	899.2	4.330	0.086	0.000121	6.250	56.88	37.500	12.990
10	11	5	6.9	81		7.4	2.8	11	902.3	5.810	0.116	0.000162	8.390	76.35	50.340	17.430
11	13	2.6	7.3	68		7.7	3.2	9	904.2	6.410	0.128	0.000179	9.250	84.18	55.500	19.230
12	17	6	11	43		7.8	3.6	7	902.8	7.000	0.140	0.000195	10.100	91.91	60.600	21.000
13	18.6	6.6	12.4	45		7.4	4.1	7	901	7.000	0.140	0.000195	10.100	91.91	60.600	21.000
14	16.4	9.8	11.1	72		0.6	3.1	7	899.1	7.000	0.140	0.000195	10.100	91.91	60.600	21.000
15	13	7.4	8.9	87		7.5	1.3	12	899.6	5.510	0.110	0.000154	7.950	72.35	47.700	16.530
16	12.4	6	8.8	90		7.2	2.2	9	900.5	6.410	0.128	0.000179	9.250	84.18	55.500	19.230
17	15.8	7	10.6	83		7.5	1.8	7	899.7	7.000	0.140	0.000195	10.100	91.91	60.600	21.000
18	17	7.6	11.7	55		7.8	4.2	12	900.7	5.510	0.110	0.000154	7.950	72.35	47.700	16.530
19	18.4	9	14.4	34		7.6	4.7	12	901.2	5.510	0.110	0.000154	7.950	72.35	47.700	16.530
20	23	12	15.5	40		7.6	2.1	6	899.6	7.300	0.146	0.000204	10.540	95.91	63.240	21.900
21	15	10.8	11.1	97		0	2.2	6	897.8	7.300	0.146	0.000204	10.540	95.91	63.240	21.900
22	16.6	8	11	79		7.5	0.4	4	897.3	7.890	0.157	0.000220	11.390	103.65	68.340	23.670
23	13	6.6	9.5	67		7.7	3.7	10	895.5	6.110	0.122	0.000170	8.820	80.26	52.920	18.330
24	10	6	8.1	72	10	6.5	3	23	894.3	2.250	0.045	0.000063	3.250	29.58	19.500	6.750
25	7	4	6	99	40	0	1.5	18	898.1	3.730	0.074	0.000104	5.380	48.96	32.280	11.190
26	10	6	7	98		2.2	3.5	11	902.1	5.810	0.116	0.000162	8.390	76.35	50.340	17.430
27	11	5	6.9	83		7.7	4	12	904.6	5.510	0.110	0.000154	7.950	72.35	47.700	16.530
28	14	4	7.9	71		7.5	4	9	902.5	6.410	0.128	0.000179	9.250	84.18	55.500	19.230
29	15	6	10.1	58		7.7	4.5	5	899.7	7.590	0.151	0.000212	10.960	99.74	65.760	22.770
30	13	7.4	10.7	55		0.1	5	9	896.8	6.410	0.128	0.000179	9.250	84.18	55.500	19.230
31	11.6	5	7.8	86		5.2	3.5	8	896.8	6.700	0.134	0.000187	9.670	88.00	58.020	20.100
Total					60.3		96.4									
Av.	14.4	6.9	9.9	65		6.1	3.1	9.5	900.1	6.3	0.125	0.000175	9.039	82.26	54.236	18.786
Max.	23	12	15.5	99	40	8	5	23	904.6	7.89	0.157	0.000220	11.390	103.64	68.337	23.670
Min.	7	2.6	6	22	0.3	0	0.4	4	894.3	2.25	0.045	0.000063	3.248	29.56	19.488	6.750
Total													**280.170**	**2549.55**	**1681.02**	**582.360**

Diesel Consumption (L/day)	Conversion Ltr Diesel to kWh	Cost of Diesel (NIS)	CO2
285.340	**2596.59**	1712.040	593.040
247.297	**2250.40**	1483.782	513.930
278.691	**2536.09**	1672.146	579.180
280.170	**2549.55**	1681.020	582.360
1091.498	**9932.63**	**6548.988**	**2268.510**

Boiler Analysis during 2012 (Jan, Feb, Nov, Dec).

Boiler

Appendix E4

Palestine Met. Office									
T.Monthly Return									
Station: Hebron									
Month : January (1)					Year: 2012				
	Temp.			Q (Heating Load)	Water Flow Rate(kg/s)	Fuel Flow Rate (kg/s)	Diesel Consumption/Day	Cost (NIS)/Day	CO2 Emmission
Day	Max.	Min.	Av.	(kW)	QL/Cp.(Ts-Tr)	mf=QHL/(ζ*Heating Value)	Litre/Day	w*cost per kWh	(kg)
1	28	1	19	8.780	0.175	0.000245	25.34859	152.09153	55.50
2	20	2	10	8.490	0.169	0.000237	24.51133	147.06801	29.25
3	12	3	7	8.190	0.163	0.000229	23.64521	141.87126	21.75
4	12	4	8	7.890	0.157	0.000220	22.77908	136.67451	24.00
5	12	4	7	7.890	0.157	0.000220	22.77908	136.67451	20.25
6	24	6	13	7.300	0.146	0.000204	21.07571	126.45423	39.00
7	12	0	8	9.080	0.181	0.000253	26.21471	157.28828	22.50
8	36	6	22	7.300	0.146	0.000204	21.07571	126.45423	64.50
9	18	6	12	7.300	0.146	0.000204	21.07571	126.45423	36.75
10	10	4	6	7.890	0.157	0.000220	22.77908	136.67451	18.75
11	32	8	20	6.700	0.134	0.000187	19.34346	116.06074	60.00
12	28	10	17	6.110	0.122	0.000170	17.64008	105.84046	51.00
13	36	13	23	5.220	0.104	0.000146	15.07057	90.42344	68.25
14	14	8	12	6.700	0.134	0.000187	19.34346	116.06074	34.50
15	18	0	8	9.080	0.181	0.000253	26.21471	157.28828	22.50
16	12	4	8	7.890	0.157	0.000220	22.77908	136.67451	24.00
17	18	4	10	7.890	0.157	0.000220	22.77908	136.67451	29.25
18	14	4	9	7.890	0.157	0.000220	22.77908	136.67451	27.00
19	16	6	12	7.300	0.146	0.000204	21.07571	126.45423	36.00
20	12	4	9	7.890	0.157	0.000220	22.77908	136.67451	25.50
21	8	4	6	7.890	0.157	0.000220	22.77908	136.67451	17.25
22	30	8	15	6.700	0.134	0.000187	19.34346	116.06074	45.75
23	16	4	9	7.890	0.157	0.000220	22.77908	136.67451	27.00
24	10	4	6	7.890	0.157	0.000220	22.77908	136.67451	18.75
25	12	4	9	7.890	0.157	0.000220	22.77908	136.67451	25.50
26	24	6	13	7.300	0.146	0.000204	21.07571	126.45423	37.50
27	50	16	31	4.330	0.086	0.000121	12.50107	75.00642	91.50
28	20	6	12	7.300	0.146	0.000204	21.07571	126.45423	34.50
29	8	4	5	7.890	0.157	0.000220	22.77908	136.67451	15.00
30	20	4	12	7.890	0.157	0.000220	22.77908	136.67451	36.00
31	40	6	16	7.300	0.146	0.000204	21.07571	126.45423	48.75
Av.	20.065	5.258	11.911	7.518	0.150	0.000210	21.70434	130.22607	35.73
Max.	50.000	16.000	30.500	9.080	0.181	0.000253	26.21471	157.28828	91.50
Min.	8.000	0.000	5.000	4.330	0.086	0.000121	12.50107	75.00642	15.00
Total					0.000	0.000000	**672.835**	**4037.008**	**1107.75**

Palestine Met. Office

T.Monthly Return

Station: Hebron

Month : February (2) Year: 2012

Day	Temp. Max.	Min.	Av.	Q (Heating Load) (kW)	Water Flow Rate(kg/s) QL/Cp.(Ts-Tr)	Fuel Flow Rate (kg/s) mf=QHL/(ζ*Heating Value)	Diesel Consumption/Day Litre/Day	Cost (NIS)/Day w*cost per kWh	CO2 Emmission (kg)
1	4.8	3	15.3	8.190	0.163	0.000229	23.645	141.871	45.75
2	7	3	8.5	8.190	0.163	0.000229	23.645	141.871	25.50
3	12	3	11.3	8.190	0.163	0.000229	23.645	141.871	33.75
4	12	5	13.5	7.590	0.151	0.000212	21.913	131.478	40.50
5	13.6	5	10.5	7.590	0.151	0.000212	21.913	131.478	31.50
6	15	6.8	9.0	7.060	0.141	0.000197	20.383	122.297	27.00
7	13	9	12.0	6.410	0.128	0.000179	18.506	111.037	36.00
8	8	1	8.5	8.780	0.175	0.000245	25.349	152.092	25.50
9	10	3	7.5	8.190	0.163	0.000229	23.645	141.871	22.50
10	7	3.8	13.0	7.950	0.158	0.000222	22.952	137.714	39.00
11	11	3	7.8	8.190	0.163	0.000229	23.645	141.871	23.25
12	13.6	5.5	10.8	7.450	0.149	0.000208	21.509	129.053	32.25
13	17.6	6.6	10.3	7.120	0.142	0.000199	20.556	123.336	30.75
14	17	8	9.3	6.700	0.134	0.000187	19.343	116.061	27.75
15	15	12	10.0	5.510	0.110	0.000154	15.908	95.447	30.00
16	6	4	13.5	7.890	0.157	0.000220	22.779	136.675	40.50
17	9	3	26.0	8.190	0.163	0.000229	23.645	141.871	78.00
18	3	0	18.0	9.080	0.181	0.000253	26.215	157.288	54.00
19	5	-1	2.2	9.380	0.187	0.000262	27.081	162.485	6.60
20	8	5	9.8	7.590	0.151	0.000212	21.913	131.478	29.25
21	11.4	1.2	14.5	8.720	0.174	0.000243	25.175	151.052	43.50
22	14	3.4	11.0	8.070	0.161	0.000225	23.299	139.793	33.00
23	16	6.0	5.3	7.300	0.146	0.000204	21.076	126.454	15.75
24	13.6	8	12.0	6.700	0.134	0.000187	19.343	116.061	36.00
25	10	4.6	10.5	7.710	0.154	0.000215	22.259	133.556	31.50
26	11	5.4	7.0	7.480	0.149	0.000209	21.595	129.572	21.00
27	12	6	7.8	7.300	0.146	0.000204	21.076	126.454	23.25
28	15.6	8	13.5	6.700	0.134	0.000187	19.343	116.061	40.50
29	8	3.4	31.5	8.070	0.161	0.000225	23.299	139.793	94.50
Av.	11.007	4.645	11.705	7.700	0.154	0.000215	22.230	133.377	35.12
Max.	17.600	12.000	31.500	9.380	0.187	0.000262	27.081	162.485	94.50
Min.	3.000	-1.000	2.200	5.510	0.110	0.000154	15.908	95.447	6.60
Total							644.657	3867.941	1018.35

Palestine Met. Office

T.Monthly Return

Station: Hebron

Month : November (11) **Year: 2012**

Day	Temp. Max.	Min.	Av.	Q (Heating Load) (kW)	Water Flow Rate(kg/s) QL/Cp.(Ts-Tr)	Fuel Flow Rate (kg/s) mf=QHL/(ζ*Heating Value)	Diesel Consumption/Day Litre/Day	Cost (NIS)/Day w*cost per kWh	CO2 Emmission (kg)
1	29.5	20.4	23.4	3.020	0.060	0.000084	8.719	52.314	70.05
2	29	20.5	23.1	2.990	0.060	0.000083	8.632	51.794	69.38
3	27	19	22.3	3.430	0.068	0.000096	9.903	59.416	66.83
4	26.5	17.8	21.1	3.790	0.076	0.000106	10.942	65.652	63.30
5	26.4	19	21.4	3.430	0.068	0.000096	9.903	59.416	64.05
6	26	16.6	21.1	4.150	0.083	0.000116	11.981	71.888	63.23
7	25	16	19.6	4.330	0.086	0.000121	12.501	75.006	58.65
8	25	16.6	18.8	4.150	0.083	0.000116	11.981	71.888	56.48
9	17	14	14.7	4.920	0.098	0.000137	14.204	85.227	44.10
10	16	10.4	12.8	5.990	0.119	0.000167	17.294	103.762	38.33
11	14.6	11	11.4	5.810	0.116	0.000162	16.774	100.644	34.28
12	12.4	9.4	10.6	6.290	0.125	0.000176	18.160	108.959	31.80
13	15.4	9.4	11.8	6.290	0.125	0.000176	18.160	108.959	35.48
14	17.4	10.4	13.7	5.990	0.119	0.000167	17.294	103.762	41.18
15	18	11.8	14.2	5.570	0.111	0.000155	16.081	96.486	42.60
16	20	11	14.8	5.810	0.116	0.000162	16.774	100.644	44.40
17	21	12	16.3	5.510	0.110	0.000154	15.908	95.447	48.90
18	21	14.4	16.5	4.800	0.096	0.000134	13.858	83.148	49.35
19	17	12	13.8	5.510	0.110	0.000154	15.908	95.447	41.25
20	18.4	11	14.2	5.810	0.116	0.000162	16.774	100.644	42.53
21	20.4	11.4	15.3	5.690	0.113	0.000159	16.428	98.565	45.75
22	19	13.0	15.0	5.220	0.104	0.000146	15.071	90.423	45.08
23	13	11.0	11.4	5.810	0.116	0.000162	16.774	100.644	34.05
24	14	10	11.5	6.110	0.122	0.000170	17.640	105.840	34.58
25	14.4	10	10.9	6.110	0.122	0.000170	17.640	105.840	32.70
26	16	9	12.1	6.410	0.128	0.000179	18.506	111.037	36.30
27	16	9	12.2	6.410	0.128	0.000179	18.506	111.037	36.60
28	17.4	10	13.3	6.110	0.122	0.000170	17.640	105.840	39.83
29	18.6	10	13.7	6.110	0.122	0.000170	17.640	105.840	41.03
30	22	12	15.6	5.510	0.110	0.000154	15.908	95.447	46.73
Av.	19.780	12.937	15.542	5.236	0.104	0.000146	15.117	90.701	46.63
Max.	29.500	20.500	23.350	6.410	0.128	0.000179	18.506	111.037	70.05
Min.	12.400	9.000	10.600	2.990	0.060	0.000083	8.632	51.794	31.80
Total							**453.503**	**2721.018**	**1398.75**

Palestine Met. Office

T.Monthly Return

Station: Hebron

Month : December (12) **Year: 2012**

Day	Temp. Max.	Min.	Av.	Q (Heating Load) (kW)	Water Flow Rate(kg/s) QL/Cp.(Ts-Tr)	Fuel Flow Rate (kg/s) mf=QHL/(ζ*Heating Value)	Diesel Consumption/Day Litre/Day	Cost (NIS)/Day w*cost per kWh	CO2 Emmission (kg)
1	21	12	15.9	5.510	0.110	0.000154	15.908	95.447	47.55
2	22	13.5	16.7	5.070	0.101	0.000141	14.638	87.825	49.95
3	23.6	12	16.6	5.510	0.110	0.000154	15.908	95.447	49.88
4	17.4	12.4	13.4	5.400	0.108	0.000151	15.590	93.541	40.28
5	10.6	8.6	9.1	6.520	0.130	0.000182	18.824	112.943	27.30
6	12	7.6	9.6	6.820	0.136	0.000190	19.690	118.139	28.80
7	13.6	8	10.4	6.700	0.134	0.000187	19.343	116.061	31.28
8	11.6	8	9.7	6.700	0.134	0.000187	19.343	116.061	29.10
9	18	8.8	12.2	6.460	0.129	0.000180	18.651	111.903	36.53
10	12	8	10.2	6.700	0.134	0.000187	19.343	116.061	30.68
11	9	4	6.8	7.890	0.157	0.000220	22.779	136.675	20.48
12	12.6	7	9.7	7.000	0.140	0.000195	20.210	121.257	28.95
13	9.5	7.4	8.1	6.880	0.137	0.000192	19.863	119.179	24.15
14	11	6.5	8.9	7.150	0.143	0.000199	20.643	123.856	26.70
15	13	7.0	8.9	7.000	0.140	0.000195	20.210	121.257	26.55
16	11	5.4	8.2	7.480	0.149	0.000209	21.595	129.572	24.53
17	12	6.5	9.5	7.150	0.143	0.000199	20.643	123.856	28.50
18	16	8	11.0	6.700	0.134	0.000187	19.343	116.061	33.00
19	14	8	11.0	6.700	0.134	0.000187	19.343	116.061	32.93
20	9	7.6	8.1	6.820	0.136	0.000190	19.690	118.139	24.15
21	7.4	4	5.9	7.890	0.157	0.000220	22.779	136.675	17.70
22	11.5	5.6	7.7	7.420	0.148	0.000207	21.422	128.533	23.18
23	14	5.0	10.4	7.590	0.151	0.000212	21.913	131.478	31.05
24	15	8	10.8	6.700	0.134	0.000187	19.343	116.061	32.40
25	10.6	7.6	8.9	6.820	0.136	0.000190	19.690	118.139	26.78
26	11.8	8.4	9.2	6.580	0.131	0.000184	18.997	113.982	27.68
27	14	7.6	9.7	6.820	0.136	0.000190	19.690	118.139	29.10
28	15.6	7	10.9	7.000	0.140	0.000195	20.210	121.257	32.63
29	15.6	7.6	10.6	6.820	0.136	0.000190	19.690	118.139	31.80
30	15	7.6	10.1	6.820	0.136	0.000190	19.690	118.139	30.30
31	14.5	7	10.2	7.000	0.140	0.000195	20.210	121.257	30.60
Av.	13.674	7.797	10.263	6.762	0.135	0.000189	19.522	117.134	30.79
Max.	23.600	13.500	16.651	7.890	0.157	0.000220	22.779	136.675	49.95
Min.	7.400	4.000	5.900	5.070	0.101	0.000141	14.638	87.825	17.70
Total							**584.981**	**3509.885**	**923.854**

Diesel Consumption (L/day)	Cost of Diesel (NIS)	CO2
672.835	4037.008	1107.750
644.657	3867.941	1018.350
453.503	2721.018	1398.750
584.981	3509.885	923.854
2355.975	**14135.851**	**4448.704**

DDH

Boiler

Appendix E-5

Palestine Met. Office T.Monthly Return Station: Hebron Year : 2011																
Day	January /Temp.			Q (Heating Load) (January)	February/Temp.			Q (Heating Load) (February)	November/Temp.			Q (Heating Load) (November)	December/Temp.			Q (Heating Load) (December)
	Max.	Min.	Av.		Max.	Min.	Av.		Max.	Min.	Av.		Max.	Min.	Av.	
1	11	7	8.2	6.11	7	4.5	5.4	5.81	21	10	13.9	6.7	15	6.6	9.9	7
2	12.8	7	9.2	6.7	6.8	4	4.7	6.7	20	10	14.5	6.41	17.5	6.4	10.8	7
3	14.8	7.6	10	7.3	9.5	2.4	6.8	6.7	17	11	13.4	6.11	16	8	11.7	6.7
4	11	7.8	8.3	6.7	13	5.5	10.4	6.11	12.4	11.8	11.4	6.11	14	8.6	10.9	6.41
5	11	6	8.2	6.7	11	5	7.7	6.7	15	9	10.7	5.81	18	8	11	6.7
6	11.6	7	8.5	7.3	11	5	8.9	5.51	14	9	11.2	4.92	16.6	7.6	10.8	7.59
7	13	6.6	8.7	7.3	14.5	7	11	5.81	16	9	12.2	6.7	15.8	7	10.6	7.3
8	7.4	5	5.3	6.11	11	6.5	8.4	6.41	17	9.4	12.5	6.7	12	7.6	9	4.92
9	10	5	6.8	6.7	12	6	8.2	6.7	18	9	13.1	7.3	10	6	7.8	4.33
10	10	5.5	7.8	6.11	9	6	6.7	7	21	11.6	16	7.59	11	5	6.9	5.81
11	14	6	9	7.3	9	5.4	6.9	6.7	24	12	23	6.41	13	2.6	7.3	6.41
12	12.8	6	9.3	6.11	9	5	6.7	7	21	14	16.8	5.51	17	6	11	7
13	12.4	5.6	8.8	4.92	11.4	5	7.4	7	20	9	14.3	6.7	18.6	6.6	12.4	7
14	14	5.8	8.5	7.3	12.4	5.2	8.7	7.59	16	11	12.5	5.81	16.4	9.8	11.1	7
15	7	4	5.9	6.7	16	7.4	11	5.51	12.8	7	9.3	3.43	13	7.4	8.9	5.51
16	10	4.5	7.2	6.11	10	7	8.5	1.95	12	6.6	9.3	3.73	12.4	6	8.8	6.41
17	12.4	7	9.5	6.7	12.5	6.5	9	7	13	9	10.5	6.41	15.8	7	10.6	7
18	11.5	7.8	8.1	3.73	16	7	11.9	6.7	12	8.4	9.5	7	17	7.6	11.7	5.51
19	13	4	8	6.7	19	11	13	5.81	10.4	7.8	8.1	6.11	18.4	9	14.4	5.51
20	15	5.5	9.3	7.3	10	8.4	8.3	3.14	11.5	6.4	8.1	6.7	23	12	15.5	7.3
21	12	5	8.4	5.51	11.5	7	8	5.81	12	7	8.3	7.3	15	10.8	11.1	7.3
22	14.5	5.6	9.7	6.7	15.5	6.5	11.2	7.89	15.6	6	10.7	7.3	16.6	8	11	7.89
23	16.5	7	11.1	7.89	17	10	13.7	7	16	8	11.3	7.3	13	6.6	9.5	6.11
24	15.6	7.5	10.3	7.3	19	9	14.1	7	13.6	8.5	10.3	7	10	6	8.1	2.25
25	14.8	7	9.5	7.3	17.4	10.5	11.5	6.11	12.5	7.4	9.3	6.41	7	4	6	3.73
26	10.5	6.4	8.4	6.7	11	5.6	7.6	4.33	13	4	7.6	7.3	10	6	7	5.81
27	16.5	7.5	11.2	5.51	12.5	6.2	9	5.81	12	4	7.6	7	11	5	6.9	5.51
28	16	7	11.8	6.7	12	7	8.9	5.51	13.5	4.6	8.6	7.59	14	4	7.9	6.41
29	16	9	12.1	5.51					13	5	8.8	7	15	6	10.1	7.59
30	10.5	8	7.5	4.33					14.4	6.8	9.6	6.7	13	7.4	10.7	6.41
31	7.5	5	6.1	4.33									11.6	5	7.8	6.7
Av.	12.4	6.3	8.7	6.4	12.4	6.5	9.1	6.1	15.3	8.4	11.4	6.4	14.4	6.9	9.9	6.3
Max.	16.5	9	12.1	7.89	19	11	14.1	7.89	24	14	23	7.59	23	12	15.5	7.89
Min.	7	4	5.3	3.73	6.8	2.4	4.7	1.95	10.4	4	7.6	3.43	7	2.6	6	2.25
DDH (Degree-Day)																
DDH=(18.3-Tavg) * N			296.6				286.53				213.49				260.1	∑(18.3-Tavg) * N
																1056.72

Average Outside Temp. during winter.(C)	**(6.3+6.5+8.4+6.9)/4**	**7.0**
Average Load for Space during winter (kW)	**(6.4+6.1+6.4+6.3)/4**	**6.3**
Theorotical Load (Q Theo.) (kJ/Season)= $\frac{\mathrm{QH} * 3600 * 24 * \mathrm{DD\ H}}{Ti - T0}\ \mathrm{Cd}$	**(6.3*3600*24*1056.72*0.77)/(21-7)**	**31635660.67**
Mass of Fuel Consumed (kg/season)= $\left(\frac{\mathrm{QH, theor}}{CV * \zeta}\right)$	**31635661/(39000*0.8)**	**1013.96**
Volume of the Diesel Tank (m3/season)= $\left(\frac{\mathrm{Mass\ of\ Fuel\ (kg)}}{Density\ of\ Fuel(\rho)}\right)$	**1013.96/850**	**1.193**

Palestine Met. Office																
T.Monthly Return																
Station: Hebron																
Year : 2012																
	January /Temp.			**Q (Heating Load) (January)**	**February/Temp.**			**Q (Heating Load) (February)**	**November/Temp.**			**Q (Heating Load) (November)**	**December/Temp.**			**Q (Heating Load) (December)**
Day	**Max.**	**Min.**	**Av.**		**Max.**	**Min.**	**Av.**		**Max.**	**Min.**	**Av.**		**Max.**	**Min.**	**Av.**	
1	**28**	**1**	**19**	**8.78**	4.8	3	15.25	8.19	29.5	20.4	23.35	3.02	21	12	15.85	5.51
2	**20**	**2**	**10**	**8.49**	7	3	8.5	8.19	29	20.5	23.125	2.99	22	13.5	16.65125	5.07
3	**12**	**3**	**7**	**8.19**	12	3	11.25	8.19	27	19	22.275	3.43	23.6	12	16.625	5.51
4	**12**	**4**	**8**	**7.89**	12	5	13.5	7.59	26.5	17.8	21.1	3.79	17.4	12.4	13.425	5.4
5	**12**	**4**	**7**	**7.89**	13.6	5	10.5	7.59	26.4	19	21.35	3.43	10.6	8.6	9.1	6.52
6	**24**	**6**	**13**	**7.3**	15	6.8	9	7.06	26	16.6	21.075	4.15	12	7.6	9.6	6.82
7	**12**	**0**	**8**	**9.08**	13	9	12	6.41	25	16	19.55	4.33	13.6	8	10.425	6.7
8	**36**	**6**	**22**	**7.3**	8	1	8.5	8.78	25	16.6	18.825	4.15	11.6	8	9.7	6.7
9	**18**	**6**	**12**	**7.3**	10	3	7.5	8.19	17	14	14.7	4.92	18	8.8	12.175	6.46
10	**10**	**4**	**6**	**7.89**	7	3.8	13	7.95	16	10.4	12.775	5.99	12	8	10.225	6.7
11	**32**	**8**	**20**	**6.7**	11	3	7.75	8.19	14.6	11	11.425	5.81	9	4	6.825	7.89
12	**28**	**10**	**17**	**6.11**	13.6	5.5	10.75	7.45	12.4	9.4	10.6	6.29	12.6	7	9.65	7
13	**36**	**13**	**23**	**5.22**	17.6	6.6	10.25	7.12	15.4	9.4	11.825	6.29	9.5	7.4	8.05	6.88
14	**14**	**8**	**12**	**6.7**	17	8	9.25	6.7	17.4	10.4	13.725	5.99	11	6.5	8.9	7.15
15	**18**	**0**	**8**	**9.08**	15	12	10	5.51	18	11.8	14.2	5.57	13	7	8.85	7
16	**12**	**4**	**8**	**7.89**	6	4	13.5	7.89	20	11	14.8	5.81	11	5.4	8.175	7.48
17	**18**	**4**	**10**	**7.89**	9	3	26	8.19	21	12	16.3	5.51	12	6.5	9.5	7.15
18	**14**	**4**	**9**	**7.89**	3	0	18	9.08	21	14.4	16.45	4.8	16	8	11	6.7
19	**16**	**6**	**12**	**7.3**	5	-1	2.2	9.38	17	12	13.75	5.51	14	8	10.975	6.7
20	**12**	**4**	**9**	**7.89**	8	5	9.75	7.59	18.4	11	14.175	5.81	9	7.6	8.05	6.82
21	**8**	**4**	**6**	**7.89**	11.4	1.2	14.5	8.72	20.4	11.4	15.25	5.69	7.4	4	5.9	7.89
22	**30**	**8**	**15**	**6.7**	14	3.4	11	8.07	19	13	15.025	5.22	11.5	5.6	7.725	7.42
23	**16**	**4**	**9**	**7.89**	16	6	5.25	7.3	13	11	11.35	5.81	14	5	10.35	7.59
24	**10**	**4**	**6**	**7.89**	13.6	8	12	6.7	14	10	11.525	6.11	15	8	10.8	6.7
25	**12**	**4**	**9**	**7.89**	10	4.6	10.5	7.71	14.4	10	10.9	6.11	10.6	7.6	8.925	6.82
26	**24**	**6**	**13**	**7.3**	11	5.4	7	7.48	16	9	12.1	6.41	11.8	8.4	9.225	6.58
27	**50**	**16**	**31**	**4.33**	12	6	7.75	7.3	16	9	12.2	6.41	14	7.6	9.7	6.82
28	**20**	**6**	**12**	**7.3**	15.6	8	13.5	6.7	17.4	10	13.275	6.11	15.6	7	10.875	7
29	**8**	**4**	**5**	**7.89**	8	3.4	31.5	8.07	18.6	10	13.675	6.11	15.6	7.6	10.6	6.82
30	**20**	**4**	**12**	**7.89**					22	12	15.575	5.51	15	7.6	10.1	6.82
31	**40**	**6**	**16**	**7.3**									14.5	7	10.2	7
Av.	**19.79**	**5.52**	**11.76**	**7.5**	11.0	4.6	11.7	7.70	19.78	12.93667	15.54167	5.236	13.67419	7.796774	10.26294	6.76
Max.	**50.00**	**16.00**	**30.50**	**9.08**	17.6	12	31.5	9.38	29.5	20.5	23.35	6.41	23.6	13.5	16.65125	7.89
Min.	**8.00**	**0.00**	**5.00**	**4.33**	3	-1	2.2	5.51	12.4	9	10.6	2.99	7.4	4.0	5.9	5.07
DDH (Degree-Day)																
DDH=(18.3-Tavg) * N			**202.78**				**204.44**				**85.51**				**249.15**	**∑(18.3-Tavg) * N**
																741.88

Average Outside Temp. during winter.(C)	(5.52+4.6+12.9+7.79)/4	7.70
Average Load for Space during winter (kW)	(7.5+7.7+5.23+6.76)/4	6.80
Theorotical Load (Q Theo.) (kJ/Season)= $\frac{\text{QH} * 3600 * 24 * \text{DD H}}{Ti - T0}\ \text{Cd}$	(6.80*3600*24*741.88*0.77)/(21-7.7)	25234540.6
Mass of Fuel Consumed (kg/season)= $\left(\frac{\text{QH, theor}}{CV * \zeta}\right)$	25234540.6/(39000*0.8)	808.80
Volume of the Diesel Tank (m3/season)= $\left(\frac{\text{Mass of Fuel (kg)}}{Density\ of\ Fuel(\rho)}\right)$	808.80/850	0.95

جامعة النجاح الوطنية
كلية الدراسات العليا

دراسة مقارنة للتدفئة تحت البلاط باستخدام المضخات الحرارية أو المراجل

إعداد
حسين اسحق حسين عوض

إشراف
د. عبد الرحيم أبو الصفا

قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة واستراتيجيات توفير الاستهلاك بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

2014م

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الملخص

إن موضوع توفير الطاقة هو أمر جوهري بالنسبة للطاقة والبيئة، خاصة عندما يكون الحديث عن أنظمة التدفئة في المباني السكنية الخاصة والعامة التي تشتهر بارتفاع معدل استهلاكها ومؤثراتها البيئية، إن الهدف الأساسي من هذه الدراسة هو مقارنة نظام المراجل التي تعمل بالوقود (السولار) بنظام المضخات الحرارية لتزويد الحرارة لنظام تدفئة تحت البلاط حيث جرت الدراسة على شقة سكنية بمساحة 78.3 متر مربع لمقارنة أداء كلا النظامين عند نفس ظروف الراحة الداخلية.

تم حساب الحمل الحراري للشقة السكنية بناء على تغير درجات الحرارة الخارجية في فصل الشتاء للأشهر (كانون الثاني، شباط تشرين ثاني، كانون أول) خلال سنة 2011، 2012 بناء على البيانات التي تم الحصول عليها من دائرة الأرصاد الجوية الفلسطينية لمدينة الخليل، كما تم حساب معامل الكفاءة التجريبية للمضخة الحرارية التي تم استخدامها باعتبار كل من درجة الحرارة للماء الساخن المزود ودرجة الحرارة الخارجية، كما تم حساب الطاقة الحرارية اللازمة للتشغيل خلال فصل الشتاء باستخدام (DDH) التي يتم من خلالها حساب كمية الوقود اللازم للتشغيل خلال فصل الشتاء.

كما تم حساب القيمة العظمى للحمل الحراري بناء على معدل درجة الحرارة (7) درجات مئوية و حساب معامل الكفاءة بناء على تلك الدرجة بقيمة 3.13. ومن خلال إجراء تحليل اقتصادي لكلا النظامين باستخدام طريقة القيمة الحالية للنظامين تبين الاستهلاك السنوي لنظام المضخة الحرارية بقيمة 2000 شيكل و 7000 شيكل لنظام المرجل الحراري، حيث تم الأخذ بعين الاعتبار نفس الدورة الزمنية لكلا النظامين 15 سنة.

النتائج البيئية للنظامين تم الحصول عليها من خلال حساب كمية انبعاث ثاني اكسيد الكربون، وتبين هناك فرق بسيط في الكمية المنتجة سنويا بقيمة 31.2 طن للمضخة الحرارية مقارنة مع المرجل الحراري بقيمة 33 طن سنويا، وهذا الفرق البسيط يعزى لطريقة توليد الكهرباء المتبعة في المنطقة حيث يستخدم الفحم لإنتاج الطاقة الكهربائية.