

# ESTIMATING THE SEASONAL COEFFICIENT OF PERFORMANCE OF HEAT PUMP WATER HEATERS IN NORTH CYPRUS

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To my Parents

### ABSTRACT

In this research a method was devised in order to estimate the maximum possible COP11p for a heat pump water heater by employing a number of serial reversible Carnot heat pumps. Each increases the water side temperature only by 1°C which is negligible.

Also COP11p for both the reversed Carnot cycle operated as a heat pump and that of the ideal vapor compression refrigeration cycle were determined by using the parameters i.e. the condensation and evaporation temperatures, and the parameters were used in the region of interest (North Cyprus). The values are calculated and represented graphically and as well compared. For a heat pump water heater which is available in North Cyrus market (Aldea AL- IPB 190).SCOP is obtained theoretically for local usage conditions.

For five months period i.e. from November 2006 - March 2007 the calculations based on this five months were used for the comparism with another different heating system other than solar water heaters i.e. the electric water heaters.

Furthermore, in this study the metrological data for Nicosia from November 2006 - March 2007 were obtained from the North Cyrus metrological laboratory. For three different working mode of the unit, the water is to be heated for the range of temperature  $(15^{\circ}C - 45^{\circ}C)$ ,  $(15^{\circ}C - 55^{\circ}C)$  and  $(15^{\circ}C - 60^{\circ}C)$ . Daily COP values were obtained for daily minimum surrounding temperatures, circadian average and daily maximum surrounding temperatures, and were obtained by using the COP surrounding temperature graph given by the user's manual of the unit, and SCOP was defined based on the values of the five months Period with COP values.

Finally, for heating the water, electric consumption cost is compared by using the electric heater and the Aldea heat pump cases only by considering criteria and payback period was obtained for the heat pump unit.

Keywords: Heat pump water heater; heat pump; reversed Carnot cycle; COP; SCOP

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## ÖZET

Bu çalı mada bir ısı pompası su ısıtıcısına yönelik en yüksek performans katsayının belirlenmesi için bir hesplama yöntemi önerilmi tir. Bu yöntem her biri su tarafında sadece 1°C'lik ihmaledilebilir bir sıcaklık farkı yaratan, seri olarak çalı an bir dizi tersinir Carnot ısı pompasını içermektedir.

Ayrıca, ısı pompası eklinde kullanılan ters Carnot ve deal Buhar Sıkı tırmalı So utma Çerimlerine ait COPhp de erleri, ilgi çalı ma aralı ında çevrimlerdeki sabit yo u ma ve buharla ma sıcaklıkları parametre olarak kullanılarak hesaplanıp, grafiksel olarak verilmi ve kar ıla tırılmı tır.

Kuzey Kıbrıs piyasasında mevcut bir ısı pompası su ısıtıcı için (Aldea AL- IPB 190) lokal kullanım ko ullarındaki Sezonluk Performans Katsayısı SCOP, teorik olarak elde edilmi tir. Hesplama, sıcak kullanım suyu elde etmek için güne enerjisi dı ında bir ba ka ısıtma sisteminin yaygın olarak kullanıldı ı Kasım - Mart ayları arasındaki be aylık bir periyodu baz almaktadır. Çalı mada Lefko a için Kuzey Kıbrıs Türk Cumhuriyeti Meteoroloji Dairesinden temin edilmi Kasım 2006 - Mart 2007 dönemine ait meteorolojik veriler kullanılmı tır. Ürüne ait üç farklı çalı ma ekli için (suyun 15°C'den 45°C'ye ısıtılması, suyun 15°C'den 55°C'ye ısıtılması, suyun 15°C'den 60°C'ye ısıtılması) günlük en dü ük, günlük ortalama ve günlük en yüksek dı ortam sıcaklıklarında ürünün kullanma kılavuzunda belirtilen Performans Katsayısı - Dı Ortam Sıcaklı ı grafi i kullanılarak günlük Performans Katsayıları belirlenmi ve bunların be aylık periyottaki ortalama de erleriyle Sezonluk Performans Katsayısları elde edilmi tir.

Son olarak suyun elektrikli ısıtıcı ve Aldea ısı pompası kullanılarak ısıtılması durumlarındaki elektrik tüketim maliyetleri kar ıla tırılmı ve sadece bu kriter göz önüne alınarak ürün için bir geri ödeme süresi elde edilmi tir.

Anahtar kelumeler: Isi pompasi su isitiasi; Ters Carnot çevirmi; Isi pompasi; COP; SCOP

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# ABBREVIATIONS AND SYMBOLS

WHs:	Water heaters					
HPs:	Heat Pumps					
HPWHs:	Heat pump water heaters					
COPhp:	Coefficient of performance of heat pump					
SCOP:	Seasonal coefficient of performance					
ASHP:	Air source heat pump					
Wnet,in:	Net work done on the system					
Q <sub>out</sub> :	Useful work done					
<b>TH</b> :	High temperature or the condenser temperature					
T <sub>L</sub> :	Low temperature or the evaporator temperature					
h:	Enthalpy					
IVCRC:	Ideal vapor compression refrigeration cycle					
N:	Number of stages					
Ti:	Initial temperature for the tank					
Tr:	Final temperature for the tank					
sr:	Change in temperature					
T <sub>max</sub> :	Maximum temperature					
T <sub>avg</sub> :	Average temperature					
Tmin:	Minimum temperature					
C <sub>P</sub> :	Specific heat capacity of water					
M:	Mass of water					
RCC:	Reversed camot cycle					

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Tmin:	Minimum temperature
C <sub>P</sub> :	Specific heat capacity of water
M:	Mass of water
RCC:	Reversed camot cycle

# CHAPTER 1 INTRODUCTION

### 1.1 Introduction

Hot water supply in residential huidiogn, is for both public and commercial purposes among the largest Energy end uses that accounts for approximately 19-50% of the sum total of the energy consumption of countries worldwide, for which there is a significant ability for energy savings (Abel et al., 2015). Most of the residential water heaters (WHs) in use today are equipped with conventional heaters that generate heat in exchange by consuming fuels or electricity. For example, the installation and operation of electric water heaters seem convenient, but the overall efficiency of the conversion process i.e. from the potential energy of fossils fuels into electric energy, then to thermal energy is absolutely low, Compared to those WHs, Heat pump (HP) water heating system can supply much more heat with just the same electric input used for conventional heaters (Arif and Yildiz, 2009).

### 1.2 Water Heaters

Water heaters are efficient way, in which water is been heated and supplied to homes and other places for various uses, depending on the consumer choice and demand. The nature of the environment, the amount of hot water needed to be supplied i.e. either it is for small number of family or a larger family helps the consumers select the most appropriate type of water heater that will be economically wise for their consumption.

#### 1.3 Types of Water Heaters

Water heaters are of different types among which includes conventional storage water heaters, solar water heaters, and Heat pump water heaters.

### 1.3.1 Conventional storage water heaters

Conventional storage water heaters are the most commonly and popularly type of water heater systems used in homes and buildings, the sources of energy for this type of water heaters includes natural gas, propane, fuel oil and electricity.

They consist of the cold water inlet and a tap for the hot water from the top of it.

It operates by releasing hot water from the top simply by putting the hot water tap on, and to replace back the hot water that has been used, cold water enters the bottom of the tank which get heated by the gas burner at the bottom of the tank. As shown in the Figure 1.1 a below.



Figure 1.la: Conventional Storage Water Heater

Gas values are open by the thermostat as the water temperature falls, and closes when the temperature of the water rises and insulation is made to prevent or minimize heat loss from the water heater to the surrounding.

### **1.3.2 Solar water heaters**

This are also called solar domestic hot water systems, they can be a cost-effective means of generating hot water in homes, also can be used in almost all the climates, and they used direct sun shine as their source of energy through the flat plate collector to heat water. They are mainly of two types i.e. the active solar water heating systems and the passive solar water heating systems.

For active direct circulation system, pump is used to circulate water through the collectors and then into the home. Hence they work better in climates that rarely freezes. On the other hand for the active indirect circulating systems a pump circulate a non-freezing heat-transfer fluid through the collectors and then to the heat exchanger as demonstrated in Figure 1.1b below.



Figure 1.lb: Active solar water heating system

This heats the water and then move it to the home. They work well in climate that is prone to freezing temperatures.

The passive solar water heating system requires no pump, rather water is moved by natural convection from solar collector to the storage tank as the water is getting heated.

They are basically less expensive than the active systems, but usually not efficient as the active types. However they are considered to be reliable and may also last longer.



Figure 1.2: Passive solar water heating system

#### 1.4 Heat Pump Water Heaters

Heat pump water heaters use electricity to move heat from one place to another instead of generating heat directly. Therefore, they can be three times more energy efficient than the conventional electric resistance water heaters. As an example the unit COP under consideration in this study is declared as 3.6. In order to move the heat, heat pump work like a refrigerator in reverse.

While a refrigerator extracts heat from inside box and disperse it into the surrounding, an air source heat pump water heater pulls heat from the surrounding air and dumps it at a higher temperature into a tank to heat water. Therefore the aim of the heat pumps here is to heat water. They are available for purchase either as an integrated unit with a built in water storage tank or as a separate unit i.e. the heat pump and the tank are separated. (EEFS, 2008).

#### 1.4.1 Benefits of heat pump water heaters

Heat pump water heaters serves as an alternative way of providing hot water, the heat pump when in use, continuously exhausts cool air as a result of the heat they extract from the ambient air.

Also HPWH units are purposely designed and manufactured for low power consumption when compared to electric resistance water heaters. As such they provide the potential for a highly reduced electrical demand costs especially in areas where the site demand for hot water is high but with insufficient electricity supply (Ted et al., 1995).

#### 1.4.2 Disadvantages of heat pump water heaters

The ritajor disadvantage of this type of water heaters is lower COP when the' ambient temperature is very low, high initial cost, i.e. the cost of purchase as well as the installation cost is also a huge problem with this systems. Also technical difficulties in installing these units of heat pumps is another major problem i.e. (poor installation) will result in a high running cost of the unit.

Another disadvantage of heat pump water heaters is that they are scarce, that is they are not sufficiently available in the markets.

#### 1.5 Coefficient of Performance of a Heat Pump (COPhp)

The coefficient of performance is a measure of the amount of power input to a system compared to the amount of power output by the system.

Also defined as the energy produced by the heat pump (in watts) divided by the energy consumed by the heat pump (in watts) therefore it gives the electricity consumption needed to meet heating demand at a given temperature (USDE, 1995).

### 1.5.1 Seasonal coefficient of performance (SCOP)

Seasonal Coefficient of Performance (SCOP) describes the heat pump's average annual efficiency performance, as such SCOP is therefore an expression for how good and efficient a specific heat pump will be for a given heating demand. Hence knowing the SCOP will help the consumer in purchasing the proper unit of heat pump to consider (USDE, 1995).

### 1.6 Aim of the Research

The aim of this research is to estimate theoretically the seasonal coefficient of performance (SCOP) of a heat pump water heater in north Cyprus. Also to estimate the benefits and the payback period for heat pump used in heating water.

# CHAPTER2 SURVEY

#### 2.1 Literature Survey

Heat pump systems offer the economical alternative of providing heat from different sources for use in various industrial, commercial and residential application. As the cost of energy continues to rise, it becomes imperative to save energy and improve overall energy efficiency. In this view, the heat pump becomes a key component in an energy utilization system with great potential for energy saving. Improving heat pump performance, reliability, and its environmental impact has seen an ongoing concern.

Recent progress in heat pump systems have centered upon advanced cycle designs for both heating and cooling systems, improved cycle component including the choice of the working fluid. For a heat pump to be a better economical proposal, continuous efforts need to be devoted in other to prolong its performance and durability while discovering novel applications. Some of the recent research findings and efforts have significantly improved the efficiency of the heat pump (Abel et al., 2015).

Findings also indicate that the level of service and energy performance of an air source heat pump water heaters (ASHPWH) are mostly influenced by their coefficient of performance and site- specific electricity tariff respectively, Therefore there is need for a careful consideration of ASHPWH technical specifications based on environmental characteristics so as to support the development of energy efficiency for the heat pump water heaters (Abel et al., 2015).

A study on the performance of a reversible Ground Source Heat Pump GSHP coupled to a city water distribution system was carried out, and compared the experimental work with simulation to a typical Air -Source Heat Pump ASHP. For space conditioning i.e. both heating and cooling. GSHPs have displayed the ability of lowering high demands and the total consumption of electricity. The use of this water distribution system as a heat source/ sink promote the annual advancement of 13% in capacities and an annual improvement of 14% in COPs respectively. Particularly at low ambient air temperatures, GSHPs have essential heating capacity (24%) and improved efficiency of (20%) over the ASHPs. The cycle layout is shown in Figure 2.1 (Swardt and Meyer, 2001).



Figure 2.1: Cycle layout

The most basic and popularly type of HP for domestic use, are termed as "conventional" HP, the air source system which extract heat from the air ( heat source) at a given point and convey it to air (heat sink) at another location. While in the winter period, a heat pump acquires heat from the outside air and transfer the heat to the required space or home via the working fluid. When temperature of the outside surrounding drops below -3.88, -1.1°C, the ASHP then uses electric resistance heat. During the summer period the HP reverses the process by removing heat from the required space and transfer it to outside air (Hepbasli et al., 2003).

A new - air conditioning product that could accomplish the multi - functions with enhanced energy performance was brought into practice. According to the basic design principles and laboratory test results. *The* results revealed that by incorporating a WH in the outdoor unit of a split - type air conditioner, in order that space cooling and water heating could take place at the same time, the energy performance could be raised significantly. Two slightly different prototypes design were constructed for testing performance. COP averaged, for space cooling and water heating, space heating only and water heating only, was obtained as 4.02, 2.91, 2.72 and 2.00 respectively at 4.5 ambient temperature (Ji et al., 2003).

Seasonal performance evaluation methods for WHs was surveyed, and the experimental method for scaling ASHPWHs was presented. It follows that the method of rating this units was based on the performance measured during heating operation of a specific products rather than a very comprehensive simulation model of HP performance.

The performance measured was used in a correlation model of the HP unit in an annual cycle system performance. The two tested ASHPWHs had a noticeable lower performance than the normal solar WHs or solar - boosted HPWHs. The ASHPWHs could be used in places where solar WHs can not be applicable. The schematic diagrams are given in Figure 2.2 (Morrison et al., 2004).



Figure 2.2: ASHPWH with wrap- around condenser coil and ASHPWH with external condenser

A specific heat pump system that could work out the problem of low heating capacity at low ambient temperature is described. This is one of the enormous difficulty in the ASHP systems. In a sequence to reduce the collector area required during the daytime, the HP system worked by the air - source, and at night or at a very low ambient temperature it could be operated with hot water, which has been produced during the daytime by the collector. The hot water supply system included a supplementary electric heater. The experiment was carried out with a prefabricated test house, which was constructed with double glazed windows with high thermal insulation. The outcome of this experiment reveals that solar energy improved the total electric energy savings, also at low ambient temperature increased the heating capacity and eliminated the requirement for reverse cycle defrosting operation (Arif and Yildiz, 2009).

A simulation study on the performance operation of a new designed solar- air source heat pump water heater (SAS- HPWH)was carried out, it follows that the SAS-HPWH operates with a specially designed flat- flate heat collector/evaporator with spiral- finned tubes in order to acquire energy from both solar irradiation and ambient air for heating water. According to the data used for this experiment, based on 150L water heating capacity. Showed that SAS-HPWH could heat the water up to 55°C efficiently subject to different weather conditions all year round. Figure 2.3 shows the schematic diagram for illustration purposes (Guoying et al., 2006).



Figure 2.3. Schematic diagram of the experimental set- up

## 2.1.1 A brief historical development of heat pumps

Heat pump used for heating water or space conditioning were initiated in the year 1948, which is indeed a great achievement in the western hemisphere. The theoretical conception of the HP was described in a neglected book, published in the year 1824. Written by young French army officer, Sadi Carnot. Its practical application on a large scale is attributable to some building engineers, and designers. A tremendous credit is usually given to Irish scientist William Thomson (Lord Kelvin) for the concept of the heat pump even though he did not have the resource to construct one. The first English inventor of this device T.G.N Haldane was awarded in 1927 (Arif and Yildiz, 2009).

The first commercial Heat pump installation was in the United States in 1948, whereas in early 1950s commercial distribution of heat pump units was initiated, suffered declines in the 1960s due to a poor record of reliability, but rapid growth were registered in the 1970s,

when higher electricity costs made electric furnace less competitive and the improved quality control increases the attractiveness of HPs.

Geothermal HPs world largest installation was recorded in 1996, at the United States Army's fort Polk military base in Leesville, Louisiana. The installation of these units replaced 3243 ASHPs and 760 central air conditioning and natural gas forced air furnace system for up to 4003 housing units (Arif and Yildiz, 2009).

### 2.2 Market Survey

Heat pump market is anticipated to grow at an estimated growth of more than 7% from 2015 to 2022. The growth is characterized based on the increased demand for renewable energy sources along with a wider support from government in form of like subsidies and other monetary benefits.

Only few models of heat pump water heater (HPWHs) are presently available on the market and are sold at high cost e.g. the Aldea heat pump model (AL-IPB 190) that cost up to about \$2000 due to the unavailability of the heat pump units, even more in countries like United State and Japan that manufacture most of the world consumed units also experience such a decline in their respective markets with just few models available. The market for heat pump water heaters has been steadily declining since the 1980s (EEFS, 2008).

Furthermore, Heat pump water heaters are also available in the market from several U.S manufacturers, including, Parker Davis, Nyle international, and Aqua products. Similarly some models of heat pump water heaters from Japanese manufacturers also include Toshiba, Hitachi, Sanyo Electric, Mitsubishi, Corona and Matsushita (EEFS, 2008).

Increasing awareness regarding greenhouse gas emission from conventional heating activities is expected to lift the market of heat pumps over the forecasted period thereby replacing the conventional heating appliances. Also with daily increasing energy demand, depleting oil & gas resources, legislative support, and higher investments are the major factors driving the product demand. But lack of awareness alongside with higher initial investment costs are expected to restrain the market growth over this period. Technical difficulties in installing these units in existing infrastructures is also a major restraint for the overall growth. Lack of government support in some regions is also a key factor restraining the demand of heat pumps (Arif and Yildiz, 2009).

#### CHAPTER3

## THEORETICAL BACKGROUND

#### 3.1 Refrigeration

Refrigeration is the process of moving heat from one place to another in a controlled environment. It can also be defined as the transfer of heat from low temperature region to a high temperature region. Hence the devices resulting in refrigeration are referred to as refrigerator or heat pumps (Billy, 2002).

#### 3.2 Refrigerators and Heat Pumps

It is known from experience heat flows in the direction of decreasing temperature, that is, from higher temperature regions to that of the lower temperature regions. As it is stated by the 2nd law of thermodynamics such heat transfer occurs naturally without requiring any devices. But reversing the process however is not possible just like that, otherwise heat transfer from low-temperature to high temperature regions requires a special devices called refrigerators (Yunus and Michael, 1998).

Refrigerators are cyclic devices, and the working fluids used in refrigeration cycle are known as refrigerants. A refrigerator is schematically shown in the Figure 3.1.



Figure 3.1: Refrigerator

Here, QL is the magnitude of heat removed from the refrigerated space at temperature TL, and QH is the magnitude of the rejected heat to the warm space at temperature TH, and w<sub>net,in</sub> is the network input to the refrigerator (Yunus and Michael, 1998). Therefore, the performance of refrigerators is expressed in terms of Coefficient of Performance (COP) which is defined as

$$COP_{R} = \frac{Desired output}{Required input} = \frac{Cooling effect}{Work input} Winet, in$$
(3.1)

This relation can also be in rate form by replacing Q1 by Q1 and Wnet, in by wn:t, in-

The conservation of energy or in other words the 1st law of thermodynamics for a cyclic device requires that

$$W_{net.in} = Q_H - Q_L \tag{3.2}$$

Then the relation for the COP given in equation (3.1) can also be expressed as:

$$COPR = \frac{Q_L}{QR - QL} = \frac{1}{Q_H/Q_L - 1}$$
 (3.3)

From equation 3.3 the value for *COPR* can be greater than unity. That is, the amount of the heat removed from the refrigerated space can be greater than the amount of work input. A heat pump is another device that transfers heat from low- temperature region to a high-temperature medium. Hence heat pumps and refrigerators are essentially the same devices, but only differs in their objectives. The objective of refrigerator is to maintain low temperature at the refrigerated space by removing heat from it. But to discharge this heat to a higher temperature medium is merely a necessary part of the operation, not the purpose. The purpose of heat pump, however, is to keep up a heated space at a high temperature. This is achieved by absorbing heat from low temperature source, such as the cold outside air during winter, well water or any other source and supplying this heat to a warmer medium such as hot storage tank or a house. Figure 3.2 shows a schematic representation of heat pump (Yunus and Michael, 1998).



Figure 3.2: Heat Pump

Similarly, the performance of heat pump is also expressed in terms of the Coefficient of performance (COP) and is defined as

$$COP_{HP} = \frac{Desired \ output}{Required \ input} = \frac{Heating \ effect}{Work \ input} = \frac{Q_H}{W_{net,in}}$$
(3.4)

This relation can also be written in rate form by replacing QH by{jH and Wnet, in by  $Wn \sim t, in$ Equation 3.4 can also be expressed as

$$COP_{HP} = \frac{Q_H}{Q_H - Q_L} = \frac{1}{1 - \frac{Q_L}{Q_H}}$$
 (3.5)

#### 3.3 Reversed Carnot Cycle

Carnot cycle is a completely reversible cycle consisting of two reversible isothermal processes and two isentropic processes. For a given temperature limits it has the maximum thermal efficiency, and serves a standard against which the actual cycles are compared. Since the cycle is reversible, then all the four processes comprising the Carnot cycle can be reversed. And reversing the cycle will definitely reverse the direction of heat and work interactions. This result in a cycle that operate in a different direction, and is referred to as

reversed Carnot cycle, hence a refrigerator or heat pump operating on the reversed Carnot cycle is termed as a Carnot refrigerator or a Carnot heat pump (Yunus and Michael, 1998). Consider a reversed Carnot cycle shown in the Figure 3.3.



Figure 3.3: Reversed Carnot cycle component and T-s Diagram

Heat is absorbed isothermally by the refrigerant from the low- temperature source at  $T_i$  in the amount of  $Q_i$  (process 1-2), is compressed isentropically to state 3 in which temperature rises to *TH*, (process 2 - 3), heat is rejected isothermally to high- temperature sink at *TH* in an amount of *QH* (process 3 - 4), and is isentropically expanded to state 1 temperature drops to  $T_i$  (process 4-1).

From Clausius theorem and inequality,

$$\frac{Q_H}{Q_L} = \frac{T_H}{T_L} \tag{3.6}$$

Therefore, the Coefficient of performance of Carnot refrigerators and Carnot heat pumps respectively can be defined as

$$COPR, Carnot = \frac{1}{THIT_{i} - 1}$$
(3.7)

$$COPHP, Carnot = \frac{1}{1 - T_{l}/TH}$$
(3.8)

Notice that the Coefficient of performance for both in equations 3.7 and 3.8 increases as the difference between the two temperatures decreases, i.e. as *TH* falls or  $T_l$  rises.

The reversed Carnot cycle is considered the most efficient cycle that is operating between two temperature levels. Hence it is in order to look it as an ideal cycle for refrigerators and heat pumps even though it is known that the reversed Carnot cycle is not suitable model for refrigeration cycles due to some difficulties stated in the next paragraph (Michael and Howard, 1998).

It is not difficult to achieve the two isothermal heat transfer processes in practice since maintaining a constant pressure automatically fixed the temperature of a two- phase mixture at the saturation value. Therefore, processes 1-2 and 3-4 can be achieved closely in evaporators and condensers. However, processes 2-3 and 4-1 cannot be closely approximated in practice, because process 2-3 involves the compression of a mixture of liquid -vapor which requires a different compressor that will handle two phases, which sometimes even requires two compressors that will do the same job. And process 4-1 is the expansion of high- moisture- content refrigerant.

It seems as if the reversed Carnot cycle is executed outside the saturation region will eliminate these problems, but in such a case it will be difficult to achieve isothermal conditions during the heat absorption and heat - rejection processes. Therefore due to this problems it is concluded that the reversed Carnot cycle can not be approximated in actual devices and is not at all a realistic model for refrigeration cycles. However the reversed Carnot cycle can serve as a standard for which actual refrigeration cycles can be compared (Yunus and Michael, 1998).

## 3.4 The Ideal Vapor - Compression Refrigeration Cycle

Vaporizing the refrigerant completely before it is compressed and additionally by replacing the turbine with a throttling devices such as a capillary tube or an expansion valve is a simple way in which many of the impracticalities associated with the reversed Carnot cycle can be eliminated. The resulting cycle is called the ideal vapor compression refrigeration cycle, it is shown schematically and on the T-s diagram in the Figure 3.4 (Yunus and Michael, 1998).



Figure 3.4: Schematic and T-s diagram for the ideal vapor-compression refrigeration cycle

The vapor- compression refrigeration cycle is considered to be the most frequently used cycle for refrigerators, heat pumps and air- conditioning systems. This cycle consist of four vital processes.

By writing the 1" law of thermodynamics for the related process the following can be obtained.

Process 1 - 2 is the isentropic compression taking place at the compressor.

$$w_c = h_2 - h_1 \tag{3.9}$$

Process 2 - 3 is the constant pressure heat rejection in a condenser.

$$q_H = h_2 - h_3 \tag{3.10}$$

Process 3 - 4 throttling in an expansion device.

$$h_3 = h_4 \tag{3.11}$$

Process 4 - 1 is the constant pressure heat absorption in the evaporator.

$$q_L = h_1 - h_4 \tag{3.12}$$

In an ideal vapor- compression refrigeration cycle, at state I the refrigerant enters as a saturated vapor where it is isentropically compressed to the condenser pressure. During this isentropic compression the temperature of the refrigerant increases well above the surrounding temperature of the medium.

Next the refrigerant enters the condenser as a superheated vapor at state 2 and leaves the condenser as saturated liquid at state 3 because of the heat rejected to the surrounding.

At state 3 the saturated liquid refrigerant undergo a throttling process where the refrigerant is throttled to the evaporation pressure by passing the refrigerant through an expansion valve. During this process the temperature of the refrigerant drops below that of the refrigerated space.

At state 4 the refrigerant enters the evaporator as a low- quality saturated mixture, and therefore evaporate completely by absorbing heat from the refrigerated space.

Finally the refrigerant leaves the evaporator as a saturated vapor and again enters the compressor, completing the cycle.

In the Figure 3.4 the area under the process curve on the T-s diagram represent the heat transfer for internally reversible processes. Process 4 - 1 represent the heat absorbed by the refrigerant in the evaporator, while the process 2 - 3 under the curve represent the heat rejected in the condenser (Yunus and Michael, 1998).

The P-h diagram is another way used in the analysis of vapor - compression refrigeration cycle, as shown in Figure 3.5.





Three of the four processes in Figure 3.5 appears as straight lines, and the heat transfer in the evaporator and the condenser is proportional to the length of the corresponding process curves (Yunus and Michael, 1998).

Unlike the reversed Carnot cycle discussed earlier, the ideal vapor compression refrigeration cycle is not an internally reversible cycle as it involves an irreversible throttling process. As such the throttling process is maintained in the cycle so as to make it more realistic model for actual vapor- compression refrigeration cycle. But replacing this process by an isentropic turbine then the refrigerant will enter the evaporator at state 4 instead of state 4. There by increasing the refrigerant capacity i.e. (area under process curve 4 - 4 in Figure 3.4) and the network input would decrease (by the amount of work output of the turbine).

Hence replacing the expansion valve by a turbine is not practically suitable even more it is more expensive and complicated than the expansion valve.

The COPs of refrigerators and heat pumps operating on the vapor- compression refrigeration cycle can be expressed as: (Yunus and Michael, 1998).

$$COPR = \frac{Q_l}{Wnet,in} = \frac{h_l - h_4}{h_2 - h_l}$$
(3.13)  

$$COPHP = \frac{QH}{W_{net,in}} = \frac{h_2 - h_3}{h_2 - h_l}$$
(3.14)

Where,

hi = h9 at point 1 and h3 = hr at point 3.

# CHAPTER4 CALCULATIONS

## 4.1 Estimating the Maximum Possible\_COPhpfor a HPWH

Using the reversed Carnot cycle as a heat pump to heat water have difficulty simply because the condensation temperature is not constant, otherwise it is impossible to heat the water. Therefore Ta is to be changing continuously, as such this is a method devised in order estimate the maximum possible COPhp- This can be achieved by employing a series number of heat pumps connected in an N- stages as described by the equations below i.e. (Equations 4.1, 4.2 & 4.3)



Figure 4.1: Heat pumps series connection.

For one- stage i.e. using one Carnot heat pump

$$COP_{l} = \frac{\mathsf{TH}}{\mathsf{T}_{\mathsf{H}} - \mathsf{T}^{\mathsf{I}}},\tag{4.1}$$

For two- stages; using only two Carnot heat pump for heating the water

The COP value is calculated by:

$$COP2 = \frac{2}{\frac{T_{H1} - T_{L}}{TH1} + \frac{T_{H2} - T_{L}}{TH2}}$$
(4.2)

For N-stages; using N-number of Carnot heat pump for heating the water

$$cov; = \overline{\text{Lf}=1} \frac{N}{\text{COV}; = \overline{\text{Lf}=1}(T_{Hi}, COPa)} = \frac{N}{\sum_{i=1}^{N} [(T_{Hi} - T_L)/(T_{Hi})]}$$
 (4.3)

Where COP<sub>1</sub>, COP<sub>2</sub>, and COPN represents the Coefficient of performance of the heat pump for the first stage, second stage, for individual COP composing the cycle and N-stages respectively.

The given parameters that were considered in estimating the maximum possible COPhp are as shown in Table 4.1

PARAMETERS		[OC]
Air reservoir temperature	TL	7
Water reservoir temperature	TH	60
Initial temperature for the		
tank	Ti	15
Final temperature of the		
tank	Tf	60
Change in the temperature	Tr-Ti	45
Stage Number	45	
$\sim$ T= (between Tf and Ti)	1	

Table 4.1: Parameters considered

Carnot heat pump one will transfer limited amount of heat, therefore TH there will only be affected as small amount such as 1°C in our case, and we still consider this as a constant value i.e.  $\iota lT = 1$ °C.

Now from equations 4.1, 4.2 and 4.3 using the parameters in Table 4.1, the results in Table 4.2 were obtained as shown.

					COP for	COPforN
Staae no.	TL [K]	TH[K]	Ti [K]	Tr [K]	each cycle	staze
1	280	289	288	289	32.11	32.11
2	280	290	289	290	29.00	30.48
3	280	291	290	291	26.45	29.01
4	280	292	291	292	24.33	27.68
5	280	293	292	293	22.54	26.47
6	280	294	293	294	21.00	25.37
7	280	295	294	295	19.67	24.36
8	280	296	295	296	18.50	23.43
9	280	297	296	297	17.47	22.58
10	280	298	297	298	16.56	21.78
11	280	299	298	299	15.74	21.05
12	280	300	299	300	15.00	20.36
13	280	301	300	301	14.33	19.73
14	280	302	301	302	13.73	19.13
15	280	303	302	303	13,17	18.57
16	280	304	303	304	12.67	18.04
17	280	305	304	305	12.20	17.55
18	280	306	305	306	11.77	17.08
19	280	307	306	307	11.37	16.64
20	280	308	307	308	11.00	16.23
21	280	309	308	309	10,66	15.83
2.2	280	310	309	310	10.33	15.46
23	280	311	310	311	10.03	15.10
2.4	280	312	311	312	9.75	14.77
25	280	313	312	313	9 48	14 44
26	280	314	313	314	9 24	14 14
27	280	315	314	315	9 00	13 84
28	280	316	315	316	8 78	13.56
29	280	317	316	317	8 57	13.30
30	280	318	317	318	8 37	13.04
30	280	319	318	319	8 18	12 80
32	280	320	319	320	8 00	12.56
32	280	320	320	320	7 83	12.30
24	280	200	201	200	7.05	10 10
25	280	202	321	202	7 51	11 01
35	200	201	202	301	7 26	11 71
27	200	275	323	324	7 00	11 50
20	200	206	275	225	7 00	11 22
20	200	207	325	2020	6.06	11 15
<u>ور</u> ۱۰	200	200	207	200	6 02	10 00
<u>1</u> U /1	200	200	200	320	6 71	10.90
<u>41</u>	200	3 <u>7</u> 23	220	220	0.11	10.65
<u>4</u> 2	200	230	349	230	0.00	10.00
45	280	<u>351</u>	350	331	0.49	10.49
<u> </u>	200	354	331	334	0.38	LU.34
40	7 Z Q N	1 333	1 334	533	0.20	1 10.19

Table 4.2: Individual COPhp and overall COPhp

In order to show the variations of COPhp with respect to TH and the number of stages, the graphs of individual COPhp and the overall COPhp against number of stages and that against TH were shown as follows.



Figure 4.2: Overall COPhp against TH



Figure 4.3: Individual COPhp and the Overall COPhp against TH
4.2 Determination of COPup for Reversed Carnot Cycle

The COP11p for the reversed Carnot is determined from equation (3.8) earlier described as shown below.

$$COPHP, Carnot = \frac{1}{1 - T_{l}/TH}$$

Also the ranges of temperature for both TH and TL are respectively given below.

TH range:  $20^{\circ}$ C ~  $60^{\circ}$ C TL range:  $5^{\circ}$ C ~  $15^{\circ}$ C

Using equation 3.8 and the given ranges of temperatures the result were shown graphically in Figures 4.4 and 4.5.



Figure 4.4: Graph of COP11p against TL



Figure 4.5: COPhp variation with TH

4.3 Determination of COPbp for Ideal Vapor Compression Refrigeration Cycle In order to determine the COPhp for an ideal vapor compression refrigeration cycle, consider the use of equation 3.14 given below

$$COPhp = \frac{QH}{Wnet,in} = \frac{h_2 - h_3}{h_2 - h_1}$$

In our case the evaporator temperature was considered to be constant and taken as  $TE = 4^{\circ}C$  with different condenser temperatures.

## Assumptions

• Refrigerant flows at constant pressure through the two heat exchanger (evaporator and condenser)

- Compression process is isentropic
- Irreversibility within the evaporator, condenser and compressor are ignored
- No frictional pressure drop

The refrigerant in our case is considered to be 134a from Appendix 1.1, saturated Refrigerant 134a (liquid-vapor) temperature table.

At  $TE = 4^{\circ}C$ ,  $h_1 = h_9 = 249.53 \ k / kg$ , and  $S_1 = S_2 = S_9 = 0.9169 \ k / kgK$ 

Also from Appendix 1.2, superheated Refrigerant 134a vapor tables,

At P = 10bar,  $Tc = 39.39^{\circ}C$ ,  $h_2 = ?$ 

But at  $Tc = 40^{\circ}$ C,  $S = 0.9066 \ k]/kgK$ , and  $h = 268.68 \ k]/kg$ 

Also at

Hence

 $Tc = 50^{\circ}C, S = 0.9428 \ k / kgK, h = 280.19 \ k / kg$ 

Now to get  $h_2$  at  $Tc = 39.39^{\circ}$ C. we interpolate between the enthalpies and the entropies between  $Tc = 40^{\circ}$ C and  $Tc = 50^{\circ}$ C. From Appendix 2.

$$0.9066 \sim 268.68$$

$$0.9169 \sim h_2$$

$$0.9428 \sim 280.19$$

$$\frac{0.9169 - 0.9066}{0.9428 - 0.9066} = \frac{h_2 - 268.68}{280.19 - 268.68}$$

$$\frac{0.0103}{0.0362 - \frac{h_2 - 268.68}{11.51}}$$

$$0.118553 = 0.0362(h_2 - 268.68)$$

$$3.2749 = h_2 - 268.68$$

$$h_2 = 271.9549 \text{ kf}; kg$$

Then from Appendix 1.3, saturated refrigerant 134a (liquid-vapor) pressure table

At P = 10bar,  $h_3 = h_1 = 105.29 \ k / kg$ .

Therefore,

$$COPhp = \frac{271.9549}{271.9549} - \frac{105.29}{249.53} = \frac{166.6649}{22.4249} = \frac{7.432}{22.4249}$$

Similar calculations for other condenser temperatures were done and summarized in Table 4.3. But before providing the Table 4.3 let us now make a comparism between the COPhp for both IVCRC and that of the RCC. As such a sample calculation for RCC with the same evaporator and condenser temperatures as used for the IVCRC is given below:

$$COPhp = \frac{Tc}{T^{C} - \tau e} = \frac{T_{H}}{T_{H} - T_{I}}$$

$$COPhp = \frac{(39.39 + 273)}{(39.39 + 273) - (4 + 273)} = \frac{312.39}{35.39} = \frac{8827}{35.39}$$

Similar calculation was carried out in the same way for other condenser temperature values. The summarized result together with the comparism is given in Table 4.3 below

	Te = TL	TH = Tc			$S_1 = S_2$			. COPhP	COPhp
S/N	(0 <u>C</u> )	(D <u>C</u> )	P (Bar}	h1Kj/kg	Kj/kg.K	h2 Kj kg	h3 Kj/kg	IVCRC	RCC
							·.		
1	4	39.39	10	249.53	0.9169	271.9549	105.29	7.432	8.827
2	4	46.32	12	249.53	0.9196	275.6842	115.76	6.115	7.545
3	4	52.43	14	294.53	0.9169	278.8769	125.26	5.234	6.719
4	4	57.92	16	294.53	0.9196	281.584	134.02	4.603	6.137

### Table 4.3: Comparism between COPhp for IVCRC and that of RCC.

### 4.4 Estimation of Seasonal Coefficient of Performance (SCOP)

Seasonal Coefficient of Performance as described earlier determines the average annual efficiency of a heat pump, i.e. it gives the actual performance of the heat pump.

As such in this respect we consider the use of northern Cyprus metrological data for (Nicosia) five months i.e, from November - March 2006/2007 daily minimum, daily average and daily maximum temperatures in estimating the theoretical SCOP for three different range of temperatures.

The unit of heat pump technical specifications under consideration for this research are given in Appendix 2.

Similarly, the weather data i.e. maximum daily temperatures, average daily temperatures and minimum daily temperatures for the year 2006/2007 were provided in Tables 4.5, 4.6 and 4.7 below for the calculation of SCOP.

Maximum Daily Temperatures 2006/2007									
Days	November	December	January	February	March				
1	20.1	20.2	17.5	16.4	19.3				
2	23.0	21.4	18.4	15.9	19.8				
3	23.8	19.0	16.8	14.0	20.7				
4	20.0	18.0	17.4	14.4	20.4				
5	15.6	18.8	15.7	13.7	20.4				
6	16.8	18.2	15.1	12.6	19.8				
7	20.9	19.5	14.6	14.6	18.5				
8	19.6	19.8	16.9	15.7	19.3				
9	21.8	17.0	16.6	16.7	20.8				
10	21.5	18.0	16.1	16.9	20.2				
11.	21.4	21.5	15.6	17.4	20.0				
12	21.6	17.0	15.6	18.7	21.6				
13	23.3	19.0	16.6	17.4	· 19.4				
14	23.1	21.0	17.5	18.7	13.4				
15	20.6	17.0	16.8	15.9	12.8				
16	21.0	18.5	17.8	17.7	18.2				
17	23.6	21.0	19.8	17.8	16.7				
18	23.6	20.5	18.5	17.9	19.6				
19	22.4	20.5	16.8	19.4	19.7				
20	22.1	21.5	14.8	17.8	18.4				
21	21.3	22.0	15.7	18.9	19.9				
22	21.0	16.5	18.7	19.2	20.5				
23	21.4	13.2	18.0	18.5	21.4				
24	23.3	19.8	19.0	19.4	19.4				
25	24.0	18.5	19.0	17.3	20.4				
26	22.7	12.3	18.8	18.6	19.4				
27	23.8	8.5	18.8	17.4	20.1				
28	24.6	12.0	16.7	18.7	20.6				
29	24.8	15.9	14.2		19.4				
30	21.4	17.0	15.7		19.6				
31		15.1	15.4		19.2				

Table 4.4: Maximum daily temperatures for Nicosia

					and the second se	INA
					4 S	E.P.C.
						-ABY Z
	Table	4.5: Average d	laily temperat	ures for Nicosia	VZ LIB	RAN.
		Average Dail	y Temperatur	es.2006/2007	<u>∖?o</u>	1695
Days	November	December	January	February	Mar~:,	LEF
1	17.4	14.1	8.6	11.0	14.3	
2	17.5	12.8	10.1	13.5	14.5	
3	17.7	11.3	12.5	12.6	15.2	
4	17.6	11.2	13.0	10.7	14.2	
5	13.1	11.7	13.6	9.1	15.4	
6	12.1	11.5	11.4	8.1	14.0	
7	12.1	11.0	11.1	8.4	12.0	
8	13.1	11.6	8.8	9.9	12.1	
9	13.8	11.0	9.7	14.4	13.8	
10	14.8	11.6	14.0	13.3	13.3	
11.	15.7	12.1	14.0	11.0	17.6	
12	15.7	11.8	13.0	13.1	15.2	
13	16.6	15.0	8.8	12.8	f3.7	
14	17.4	13.2	9.9	13.1	9.3	
15	15.9	13.7	10.7	11.9	7.0	
16	14.0	11.5	10.8	12.0	10.8	
17	14.6	11.9	11.9	13.8	12.4	
18	16.2	12.2	10.4	16.1	12.7	
19	15.6	12.8	11.0	12.9	13.8	
20	14.3	13.3	12.4	12.7	14.0	
21	13.7	15.1	12.8	16.1	17.0	
22	13.6	14.6	9.8	14.1	15.0	
23	13.7	11.1	11.1	13.5	18.0	
24	13.8	10.2	13.9	14.9	15.0	
25	14.5	11.2	13.7	13.7	14.1	
26	14.4	11.4	11.8	14.5	13.1	
27	13.4	6.7	11.3	13.3	13.9	
28	14.6	7.9	10.9	12.8	14.1	
29	15.6	7.2	9.6		14.0	
30	. 14.3	9.8	9.6		14.3	
31		10.4	8.9		14.6	

Minimum Daily Temperature 2006/2007							
Days	November	December	January	February	March		
1	15.3	8.6	2.4	4.0	10.4		
2	12.0	6.5	4.8	7.6	10.4		
3	11.3	4.6	8.4	10'.9	9.8		
4	15.5	5.7	7.4	7.3	8.5		
5	8.2	4.5	12.2	5.7	12.8		
б	8.3	5.0	6.6	4.7	11.4		
7	4.7	5.0	7.3	2.9	6.7		
8	8.5	5.5	2.5	4.4	5.7		
9	7.0	5.0	3.0	8.7	8.2		
10	7.6	7.0	12.6	10.0	6.5		
11	9.0	7.0	12.7	4.9	12.2		
12	9.0	6.6	8.5	6.5	9.8		
13	9.4	10.0	1.9	7.9	8.6		
14	9.5	7.4	4.1	8.6	6.3		
15	11.7	10.0	5.0	8.3	3.1		
16	7.5	5.5	4.6	6.9	5.4		
17	5.0	4.5	5.8	7.0	6.5		
18	9.5	6.0	3.4	14.8	7.3		
19	9.2	6.5	5.2	7.3	7.1		
20	5.2	6.5	9.0	7.4	8.2		
21	6.4	9.1	8.9	13.3	10'.5		
22	7.1	3.3	3.1	10.0	8.0		
23	6.5	6.5	4.5	9.4	16.8		
24	6.6	4.5	6.7	9.2	12.4		
25	4.3	4.5	6.6	9.9	7.9		
26	6.0	9.5	5.2	11.7	8.4		
27	7.0	5.0	4.6	10.3	8.7		
28	7.5	3.0	5.4	7.0	7.7		
29	4.8	-1.0	5.5		8.2		
30	6.2	4.0	4.4		8.1		
31		6.0	2.0		10.5		

Table 4.6: Minimum daily temperatures for Nicosia



..-| ‴)

Having provided all the required informations about the unit and the weather data we can now proceed with the SCOP calculations. Now Consider the Table 4.7 obtained from the technical specifications for the specific unit of heat pump under consideration as declared by the manufacturer given in Appendices 2.2 and 2.3 (Figures).

	(15°C -60°C) TEMI	PERATURE RANGE	
SIN	Temperature °C	COP - AL- IPB 190	COP - AL - IPB 300
1	7	2.2	2.2
2	15	2.75	2.75
3	20	3.1	3.1
4	25	3.3	3.3
5	30	3.6	3.6

Table 4.7: COPhp for different temperatures for range  $(15^{\circ}C - 60^{\circ}C)$ 

From Table 4.7 the graph of COPhp against the surrounding temperatures is plotted.



COPhp VARIATION WITH TEMPERATURE



$$COPhp = 0.0603(T) + 1.8206$$

From equation (4.4) the temperatures provided for Nicosia from November - March 2006/2007 were substituted in order to determine the COPhp as shown in Table 4.9

(4.4)

	( 15 °C -	60 °C ) Ra	ange for	The Month of	November 20	)06
DATE	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.
01/11/06	20.1	17.4	15.3	2.87	2.74	3.03
02/11/06	23.0	17.5	12.0	2.88	2.54	3.21
03/11/06	23.8	17.7	11.3	2.89	2.50	3.26
04/11/06	20.0	17.6	15.5	2.88	2.76	3.03
05/11/06	15.6	13.1	8.2	2.61	2.32	2.76
06/11/06	16.8	12.1	8.3	2.55	2.32	2.83
07/11/06	20.9	12.1	4.7	2.55	2.10	3.08
08/11/06	19.6	13.1	8.5	2.61	2.33	3.00
09/11/06	21.8	13.8	7.0	2.65	2.24	3.14
10/11/06	21.5	14.8	7.6	2.71	2.28	3.12
11/11/06	21.4	15.7	9.0	2.77	2.36	3.11
12/11/06	21.6	15.7	9.0	2.77	2.36	3.12
13/11/06	23.3	16.6	9.4	2.82	2.39	3.23
14/11/06	23.1	17.4	9.5	2.87	2.39	3.21
15/11/06	20.6	15.9	11.7	2.78	2.53	3.06
16/11/06	21.0	14.0	7.5	2.66	2.27	3.09
17/11/06	23.6	14.6	5.0	2.70	2.12	3.24
18/11/06	23.6	16.2	9.5	2.80	2.39	3.24
19/11/06	22.4	15.6	9.2	2.76	2.38	3.17
20/11/06	22.1	14.3	5.2	2.68	2.13	3.15
21/11/06	21.3	13.7	6.4	2.65	2.21	3.10
22/11/06	21.0	13.6	7.1	2.64	2.25	3.09
23/11/06	21.4	13.7	6.5	2.65	2.21	3.11
24/11/06	23.3	13.8	6.6	2.65	2.22	3.23
25/11/06	24.0	14.5	4.3	2.69	2.08	3.27
26/11/06	22.7	14.4	6.0	2.69	2.18	3.19
27/11/06	23.8	13.4	7.0	2.63	2.24	3.26
28/11/06	24.6	14.6	7.5	2.70	2.27	3.30
29/11/06	24.8	15.6	4.8	2.76	2.11	3.32
30/11/06	21.4	14.3	6.2	2.68	2.19	3.11

 Table
 4.8:
 COPhp for maximum, average and minimum temperatures for November

{ 15°	C - 60°C)	RANGE	FOR THE MONTH OF DECEMBER 2006				
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.	
01/12/06	20.2	14.1	8.6	2.67	2.34	3.04	
02/12/06	21.4	12.8	6.5	2.59	2.21	3.11	
03/12/06	19.0	11.3	4.6	2.50	2.10	2.97	
04/12/06	18.0	11.2	5.7	2.50	2.16	2.91	
05/12/06	18.8	11.7	4.5	2.53	2.09	2.95	
06/12/06	18.2	11.5	5.0	2.51	2.12	2.92	
07/12/06	19.5	11.0	5.0	2.48	2.12	3.00	
08/12/06	19.8	11.6	5.5	2.52	2.15	3.01	
09/12/06	17.0	11.0	5.0	2.48	2.12	2.85	
10/12/06	18.0	11.6	7.0	2.52	2.24	2.91	
11/12/06	21.5	12.1	7.0	2.55	2.24	3.12	
12/12/06	17.0	11.8	6.6	2.53	2.22	2.85	
13/12/06	19.0	18.0	10.0	2.73	2.42	2.97	
14/12/06	21.0	13.2	7.4	2.62	2.27	3.09	
15/12/06	17.0	13.7	10.0	2.65	2.42	2.85	
16/12/06	18.5	11.5	5.5	2.51	2.15	2.94	
17/12/06	21.0	11.9	4.5	2.54	2.09	3.09	
18/12/06	20.5	12.2	6.0	2.56	2.18	3.06	
19/12/06	20.5	12.8	6.5	2.59	2.21	3.06	
20/12/06	21.5	13.3	6.5	2.62	2.21	3.12	
21/12/06	22.0	15.1	9.1	2.73	2.37	3.15	
22/12/06	16.5	14.6	3.3	2.70	2.02	2.82	
23/12/06	13.2	11.1	6.5	2.49	2.21	2.62	
24/12/06	19.8	10.2	4.5	2.44	2.09	3.01	
25/12/06	18.5	11.2	4.5	2.50	2.09	2.94	
26/12/06	12.3	11.4	9.5	2.51	2.39	2.56	
27/12/06	8.5	6.7	5.0	2.22	2.12	2.33	
28/12/06	12.0	7.9	3.0	2.30	2.00	2.54	
29/12/06	15.9	7.2	-1.0	2.25	1.76	2.78	
30/12/06	17.0	9.8	4.0	2.41	2.06	2.85	
31/12/06	15.1	10.4	6.0	2.45	2.18	2.73	

Table 4.9: COPhp for maximum, average and minimum temperatures for December

(15°C-60°C) RANGE FOR THE MONTH OF JANUARY 2007								
DATES	TMAX	TAVG	TMIN.	COP AVG.	COP MIN.	COPMAX.		
01/01/07	17.5	8.6	2.4	2.34	1.97	2.88		
02/01/07	18.4	10.1	4.8	2.43	2.11	2.93		
03/01/07	16.8	12.5	8.4	2.57	2.33	2.83		
04/01/07	17.4	13.0	7.4	2.60	2.27	2.87		
05/01/07	15.7	13.6	12.2	2.64	2.56	2.77		
06/01/07	15.1	11.4	6.6	2.51	2.22	2.73		
07/01/07	14.6	11.1	7.3	2.49	2.26	2.70		
08/01/07	16.9	8.8	2.5	2.35	1.97	2.84		
09/01/07	16.6	9.7	3.0	2.41	2.00	2.82		
10/01/07	16.1	14.0	12.6	2.66	2.58	2.79		
11/01/07	15.6	14.0	12.7	2.66	2.59	2.76		
12/01/07	15.6	13.0	8.5	2.60	2.33	2.76		
13/01/07	16.6	8.8	1.9	2.35	1.94	2.82		
14/01/07	17.5	9.9	4.1	2.42	2.07	2.88		
15/01/07	16.8	10.7	5.0	2.47	2.12	2.83		
16/01/07	17.8	10.8	4.6	2.47	2.10	2.89		
17/01/07	19.8	11.9	5.8	2.54	2.17	3.01		
18/01/07	18.5	10.4	3.4	2.45	2.03	2.94		
19/01/07	16.8	11.0	5.2	2.48	2.13	2.83		
20/01/07	14.8	12.4	9.0	2.57	2.36	2.71		
21/01/07	15.7	12.8	8.9	2.59	2.36	2.77		
22/01/07	18.7	9.8	3.1	2.41	2.01	2.95		
23/01/07	18.0	11.1	4.5	2.49	2.09	2.91		
24/01/07	19.0	13.9	6.7	2.66	2.22	2.97		
25/01/07	19.0	13.7	6.6	2.65	2.22	2.97		
26/01/07	18.8	11.8	5.2	2.53	2.13	2.95		
27/01/07	18.8	11.3	4.6	2.50	2.10	2.95		
28/01/07	16.7	10.9	5.4	2.48	2.15	2.83		
29/01/07	14.2	9.6	5.5	2.40	2.15	2.68		
30/01/07	15.7	9.6	4.4	2.40	2.09	2.77		
31/01/07	15.4	8.9	2.0	2.36	1.94	2.75		

 Table
 4.10:
 COPhp for maximum, average and minimum temperatures for January

(1	5°C- 60°C	C) RANGE	FOR T	THE MONTH	OF FEBUARY	¥ 2007
		TANG		COD ANG		GODINAN
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.
01/02/07	16.4	1 I.O	4.0	2.48	2.06	2.81
02/02/07	15.9	13.5	7.6	2.63	2.28	2.78
03/02/07	14.0	12.6	10.9	2.58	2.48	2.66
04/02/07	14.4	10.7	7.3	2.47	2.26	2.69
05/02/07	13.7	9.1	5.7	2.37	2.16	2.65
06/02/07	12.6	8.1	4.7	2.31	2.10	2.58
07/02/07	14.6	8.4	2.9	2.33	2.00	2.70
08/02/07	15.7	9.9	4.4	2.42	2.09	2.77
09/02/07	16.7	14.4	8.7	2.69	2.35	2.83
10/02/07	16.9	13.3	IO.0	2.62	2.42	2.84
11/02/07	17.4	1 <b>I.O</b>	4.9	2.48	2.12	2.87
12/02/07	18.7	13.1	6.5	2.61	2.21	2.95
13/02/07	17.4	12.8	7.9	2.59	2.30	2.87
14/02/07	18.7	13.1	8.6	2.61	2.34	2.95
15/02/07	15.9	11.9	8.3	2.54	2.32	2.78
16/02/07	17.7	12.0	6.9	2.54	2.24	2.89
17/02/07	17.8	13.8	7.0	2.65	2.24	2.89
18/02/07	17.9	16.1	14.8	2.79	2.71	2.90
19/02/07	19.4	12.9	7.3	2.60	2.26	2.99
20/02/07	17.8	12.7	7.4	2.59	2.27	2.89
21/02/07	18.9	16.1	13.3	2.79	2.62	2.96
22/02/07	19.2	14.1	IO.O	2.67	2,42	2.98
23/02/07	18.5	13.5	9.4	2.63	2.39	2.94
24/02/07	19.4	14.9	9.2	2.72	2.38	2.99
25/02/07	17.3	13.7	9.9	2.65	2.42	2.86
26/02/07	18.6	14.5	11.7	2.69	2.53	2.94
27/02/07	17.4	13.3	10.3	2.62	2.44	2.87
28/02/07	18.7	12.8	7.0	2.59	2.24	2.95

Table 4.11: COPhp for maximum, average and minimum temperatures for February

(1	5°C - 60°	C) RANG	E FOR	THE MONTH	OF MARCH	(15°C - 60°C) RANGE FOR THE MONTH OF MARCH 2007							
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.							
01/03/07	19.3	14.3	10.4	2.68	2.45	2.98							
02/03/07	19.8	14.5	10.4	2.69	2.45	3.01							
03/03/07	20.7	15.2	9.8	2.74	2.41	3.07							
04/03/07	20.4	14.2	8.5	2.68	2.33	3.05							
05/03/07	20.4	15.4	12.8	2.75	2.59	3.05							
06/03/07	19.8	14.0	11.4	2.66	2.51	3.01							
07/03/07	18.5	12.0	6.7	2.54	2.22	2.94							
08/03/07	19.3	12.1	5.7	2.55	2.16	2.98							
09/03/07	20.8	13.8	8.2	2.65	2.32	3.07							
10/03/07	20.2	13.3	6.5	2.62	2.21	3.04							
11/03/07	20.0	17.6	12.2	2.88	2.56	3.03							
12/03/07	21.6	15.2	9.8	2.74	2.41	3.12							
13/03/07	19.4	13.7	8.6	2.65	2.34	2.99							
14/03/07	13.4	9.3	6.3	2.38	2.20	2.63							
15/03/07	12.8	7.0	3.1	2.24	2.01	2.59							
16/03/07	18.2	10.8	5.4	2.47	2.15	2.92							
17/03/07	16.7	12.4	6.5	2.57	2.21	2.83							
18/03/07	19.6	12.7	7.3	2.59	2.26	3.00							
19/03/07	19.7	13.8	7.1	2.65	2.25	3.01							
20/03/07	18.4	14.0	8.2	2.66	2.32	2.93							
21/03/07	19.9	17.0	10.5	2.85	2.45	3.02							
22/03/07	20.5	15.0	8.0	2.73	2.30	3.06							
23/03/07	21.4	18.0	16.8	2.91	2.83	3.11							
24/03/07	19.4	15.0	12.4	2.73	2.57	2.99							
25/03/07	20.4	14.1	7.9	2.67	2.30	3.05							
26/03/07	19.4	13.1	8.4	2.61	2.33	2.99							
27/03/07	20.1	13.9	8.7	2.66	2.35	3.03							
28/03/07	20.6	14.1	7.7	2.67	2.28	3.06							
29/03/07	19.4	14.0	8.2	2.66	2.32	2.99							
30/03/07	19.6	14.3	8.1	2.68	2.31	3.00							
31/03/07	19.2	14.6	10.5	2.70	2.45	2.98							

Table 4.12: COPhp for maximum, average and minimum temperatures for March

Below are the graphs showing the relationship between respective COPhp and the days of the months.



Figure 4.8: COPhp based on the daily average temperatures



Figure 4.9: COPhp based on the daily minimum temperatures



Figure 4.10: COPhp based on the daily maximum temperatures



Figure 4.11: COPhp based on the maximum, average and minimum temperature

If we consider another range of temperature i.e.  $(15^{\circ}C - 45^{\circ}C)$  the same calculation procedure is used in obtaining the following results as shown in Table 4.14 below.

	(15°C - 45°C) TEMPER	RATURE RANGE	
SIN	TEMPERATURE °C	COP-AL-IPB 190	COP-AL-IPB 300
1	7	3.1	3.1
2	15	3.5	3.5
3	20	3.9	3.9
4	25	4.1	4.1
5	30	4.5	4.5





Figure 4.12: COPhp variation with temperatures for the range (15°C - 45°()

# COPhp = 0.0604T + 2.6482

(4.5)

With equation (4.5) COPhp was determined as shown in Table 4.15

( 15°C	(15°C - 45°C) RANGE FOR THE MONTH OF NOVEMBER 2006							
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.		
01/11/06	20.1	17.4	15.3	3.70	3.57	3.86		
02/11/06	23.0	17.5	12.0	3.71	3.37	4.04		
03/11/06	23.8	17.7	11.3	3.72	3.33	4.09		
04/11/06	20.0	17.6	15.5	3.71	3.58	3.86		
05/11/06	15.6	13.1	8.2	3.44	3.14	3.59		
06/11/06	16.8	12.1	8.3	3.38	3.15	3.66		
07/11/06	20.9	12.1	4.7	3.38	2.93	3.91		
08/11/06	19.6	13.1	8.5	3.44	3.16	3.83		
09/11/06	21.8	13.8	7.0	3.48	3.07	3.96		
10/11/06	21.5	14.8	7.6	3.54	3.11	3.95		
11/11/06	21.4	15.7	9.0	3.60	3.19	3.94		
12/11/06	21.6	15.7	9.0	3.60	3.19	3.95		
13/11/06	23.3	16.6	9.4	3.65	3.22	4.06		
14/11/06	23.1	17.4	9.5	3.70	3.22	4.04		
15/11/06	20.6	15.9	11.7	3.61	3.35	3.89		
16/11/06	21.0	14.0	7.5	3.49	3.10	3.92		
17/11/06	23.6	14.6	5.0	3.53	2.95	4.07		
18/11/06	23.6	16.2	9.5	3.63	3.22	4.07		
19/11/06	22.4	15.6	9.2	3.59	3.20	4.00		
20/11/06	22.1	14.3	5.2	3.51	2.96	3.98		
21/11/06	21.3	13.7	6.4	3.48	3.03	3.93		
22/11/06	21.0	13.6	7.1	3.47	3.08	3.92		
23/11/06	21.4	13.7	6.5	3.48	3.04	3.94		
24/11/06	23.3	13.8	6.6	3.48	3.05	4.06		
25/11/06	24.0	14.5	4.3	3.52	2.91	4.10		
26/11/06	22.7	14.4	6.0	3.52	3.01	4.02		
27/11/06	23.8	13.4	7.0	3.46	3.07	4.09		
28/11/06	24.6	14.6	7.5	3.53	3.10	4.13		
29/11/06	24.8	15.6	4.8	3.59	2.94	4.15		
30/11/06	21.4	14.3	6.2	3.51	3.02	3.94		

Table 4.14: COPhp for maximum, average and minimum temp for Nov. range  $(15^{\circ}C - 45^{\circ}C)$ 

(15°C-45°C) RANGE FOR THE MONTH OFDECEMBER2006							
3		5					
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.	
01/12/06	20.2	14.1	8.6	3.50	3.17	3.87	
02/12/06	21.4	12.8	6.5	3.42	3.04	3.94	
03/12/06	19.0	11.3	4.6	3.33	2.93	3.80	
04/12/06	18.0	11.2	5.7	3.32	2.99	3.74	
05/12/06	18.8	11.7	4.5	3.35	2.92	3.78	
06/12/06	18.2	11.5	5.0	3.34	2.95	3.75	
07/12/06	19.5	11.0	5.0	3.31	2.95	3.83	
08/12/06	19.8	11.6	5.5	3.35	2.98	3.84	
09/12/06	17.0	11.0	5.0	3.31	2.95	3.68	
10/12/06	18.0	11.6	7.0	3.35	3.07	3.74	
11/12/06	21.5	12.1	7.0	3.38	3.07	3.95	
12/12/06	17.0	11.8	6.6	3.36	3.05	3.68	
13/12/06	19.0	15.0	10.0	3.55	3.25	3.80	
14/12/06	21.0	13.2	7.4	3.45	3.10	3.92	
15/12/06	17.0	13.7	10.0	3.48	3.25	3.68	
16/12/06	18.5	11.5	5.5	3.34	2.98	3.77	
17/12/06	21.0	11.9	4.5	3.37	2.92	3.92	
18/12/06	20.5	12.2	6.0	3.39	3.01	3.89	
19/12/06	20.5	12.8	6.5	3.42	3.04	3.89	
20/12/06	21.5	13.3	6.5	3.45	3.04	3.95	
21/12/06	22.0	15.1	9.1	3.56	3.20	3.98	
22/12/06	16.5	14.6	3.3	3.53	2.85	3.64	
23/12/06	13.2	11.1	6.5	3.32	3.04	3.45	
24/12/06	19.8	10.2	4.5	3.26	2.92	3.84	
25/12/06	18.5	11.2	4.5	3.32	2.92	3.77	
26/12/06	12.3	11.4	9.5	3.34	3.22	3.39	
27/12/06	8.5	6.7	5.0	3.05	2.95	3.16	
28/12/06	12.0	7.9	3.0	3.13	2.83	3.37	
29/12/06	15.9	7.2	-1.0	3.08	2.59	3.61	
30/12/06	17.0	9.8	4.0	3.24	2.89	3.68	
31/12/06	15.1	10.4	6.0	3.28	3.01	3.56	

Table 4.15: COPhp for max., average and min. temp for Dec. Range ( $15^{\circ}C - 45^{\circ}C$ )

(15°C - 45°C) RANGE FOR THE MONTH OF JANUARY 2007							
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.	
01/01/07	17.5	8.6	2.4	3.17	2.79	3.71	
02/01/07	18.4	10.1	4.8	3.26	2.94	3.76	
03/01/07	16.8	12.5	8.4	3.40	3.16	3.66	
04/01/07	17.4	13.0	7.4	3.43	3.10	3.70	
05/01/07	15.7	13.6	12.2	3.47	3.39	3.60	
06/01/07	15.1	11.4	6.6	3.34	3.05	3.56	
07/01/07	14.6	11.1	7.3	3.32	3.09	3.53	
08/01/07	16.9	8.8	2.5	3.18	2.80	3.67	
09/01/07	16.6	9.7	3.0	3.23	2.83	3.65	
10/01/07	16.1	14.0	12.6	3.49	3.41	3.62	
11/01/07	15.6	14.0	12.7	3.49	3.42	3.59	
12/01/07	15.6	13.0	8.5	3.43	3.16	3.59	
13/01/07	16.6	8.8	1.9	3.18	2.76	3.65	
14/01/07	17.5	9.9	4.1	3.25	2.90	3.71	
15/01/07	16.8	10.7	5.0	3.29	2.95	3.66	
16/01/07	17.8	10.8	4.6	3.30	2.93	3.72	
17/01/07	19.8	11.9	5.8	3.37	3.00	3.84	
18/01/07	18.5	10.4	3.4	3.28	2.85	3.77	
19/01/07	16.8	11.0	5.2	3.31	2.96	3.66	
20/01/07	14.8	12.4	9.0	3.40	3.19	3.54	
21/01/07	15.7	12.8	8.9	3.42	3.19	3.60	
22/01/07	18.7	9.8	3.1	3.24	2.84	3.78	
23/01/07	18.0	11.1	4.5	3.32	2.92	3.74	
24/01/07	19.0	13.9	6.7	3.49	3.05	3.80	
25/01/07	19.0	13.7	6.6	3.48	3.05	3.80	
26/01/07	18.8	11.8	5.2	3.36	2.96	3.78	
27/01/07	18.8	11.3	4.6	3.33	2.93	3.78	
28/01/07	16.7	10.9	5.4	3.31	2.97	3.66	
29/01/07	14.2	9.6	5.5	3.23	2.98	3.51	
30/01/07	15.7	9.6	4.4	3.23	2.91	3.60	
31/01/07	15.4	8.9	2.0	3.19	2.77	3.58	

Table 4.16: COPhp for maximum, average and minimum temp for Jan. range  $(15^{\circ}C - 45^{\circ}C)$ 

(15°C-45°C) RANGE FOR THE MONTH OF FEBUARY 2007								
DATES	TMAX	TAVG.	TMIN.	COP AVG.	COP MIN.	COPMAX.		
01/02/07	16.4	11.0	4.0	3.31	2.89	3.64		
02/02/07	15.9	13.5	7.6	3.46	3.11	3.61		
03/02/07	14.0	12.6	10.9	3.41	3.31	3.49		
04/02/07	14.4	10.7	7.3	3.29	3.09	3.52		
05/02/07	13.7	9.1	5.7	3.20	2.99	3.48		
06/02/07	12.6	8.1	4.7	3.14	2.93	3.41		
07/02/07	14.6	8.4	2.9	3.16	2.82	3.53		
08/02/07	15.7	9.9	4.4	3.25	2.91	3.60		
09/02/07	16.7	14.4	8.7	3.52	3.17	3.66		
10/02/07	16.9	13.3	10.0	3.45	3.25	3.67		
11/02/07	17.4	11.0	4.9	3.31	2.94	3.70		
12/02/07	18.7	13.1	6.5	3.44	3.04	3.78		
13/02/07	17.4	12.8	7.9	3.42	3.13	3.70		
14/02/07	18.7	13.1	8.6	3.44	3.17	3.78		
15/02/07	15.9	11.9	8.3	3.37	3.15	3.61		
16/02/07	17.7	12.0	6.9	3.37	3.06	3.72		
17/02/07	17.8	13.8	7.0	3.48	3.07	3.72		
18/02/07	17.9	16.1	14.8	3.62	3.54	3.73		
19/02/07	19.4	12.9	7.3	3.43	3.09	3.82		
20/02/07	17.8	12.7	7.4	3.42	3.10	3.72		
21/02/07	18.9	16.1	13.3	3.62	3.45	3.79		
22/02/07	19.2	14.1	10.0	3.50	3.25	3.81		
23/02/07	18.5	13.5	9.4	3.46	3.22	3.77		
24/02/07	19.4	14.9	9.2	3.55	3.20	3.82		
25/02/07	17.3	13.7	9.9	3.48	3.25	3.69		
26/02/07	18.6	14.5	11.7	3.52	3.35	3.77		
27/02/07	17.4	13.3	10.3	3.45	3.27	3.70		
28/02/07	18.7	12.8	7.0	3.42	3.07	3.78		

Table 4.17: COPhp for max., average and min. temp for Feb. range (15°C- 45°C)

(15°C - 45°C) RANGE FOR THE MONTH OF MARCH 2007							
DATES	ΤΜΑΥ	TAVG	TMIN	COP AVG	COP MIN	COP MAX	
DATES 01/02/07	10.2	14 Q.	10.4	3.51	3 28	3.81	
01/03/07	19.5	14.5	10.4	3.51	3.28	3.81	
02/03/07	19.8	14.5	10.4	3.32	3.20	3.04	
03/03/07	20.7	15.2	9.8	2.51	3.24	3.90	
04/03/07	20.4	14.2	8.5	3.31	3.10	3.00	
05/03/07	20.4	15.4	12.8	3.38	3.42	3.00	
06/03/07	19.8	14.0	11.4	3.49	3.34	3.04	
07/03/07	18.5	12.0	6.7	3.37	3.05	3.//	
08/03/07	19.3	12.1	5.7	3.38	2.99	3.81	
09/03/07	20.8	13.8	8.2	3.48	3.14	3.90	
10/03/07	20.2	13.3	6.5	3.45	3.04	3.87	
11/03/07	20.0	17.6	12.2	3.71	3.39	3.86	
12/03/07	21.6	15.2	9.8	3.57	3.24	3.95	
13/03/07	19.4	13.7	8.6	3.48	3.17	3.82	
14/03/07	13.4	9.3	6.3	3.21	3.03	3.46	
15/03/07	12.8	7.0	3.1	3.07	2.84	3.42	
16/03/07	18.2	10.8	5.4	3.30	2.97	3.75	
17/03/07	16.7	12.4	6.5	3.40	3.04	3.66	
18/03/07	19.6	12.7	7.3	3.42	3.09	3.83	
19/03/07	19.7	13.8	7.1	3.48	3.08	3.84	
20/03/07	18.4	14.0	8.2	3.49	3.14	3.76	
21/03/07	19.9	17.0	10.5	3.68	3.28	3.85	
22/03/07	20.5	15.0	8.0	3.55	3.13	3.89	
23/03/07	21.4	18.0	16.8	3.74	3.66	3.94	
24/03/07	19.4	15.0	12.4	3.55	3.40	3.82	
25/03/07	20.4	14.1	7.9	3.50	3.13	3.88	
26/03/07	19.4	13.1	8.4	3.44	3.16	3.82	
27/03/07	20.1	13.9	8.7	3.49	3.17	3.86	
28/03/07	20.6	14.1	7.7	3.50	3.11	3.89	
29/03/07	19.4	14.0	8.2	3.49	3.14	3.82	
30/03/07	19.6	14.3	8.1	3.51	3.14	3.83	
31/03/07	19.2	14.6	10.5	3.53	3.28	3.81	

Table 4.18: COPhp for max., average and min. temp for March. Range (15°C - 45°C)

Similar graphs based on this range of temperatures are also plotted in other to show the relationship between the COPhp and the dates as shown in Figures below.















Figure 4.16: COPhp based on the daily minimum, average and maximum temperature

Now considering the last range of temperatures that is  $(15^{\circ}C - 55^{\circ}C)$  similar calculation procedures are adopted in obtaining the given tables and the graphs as shown below.

	(15°C-55°C) TEMPERATURE RANGE.								
	je≉ <sub>n</sub> , , ,								
SIN	<b>TEMPERATURE°C</b>	COP - AL- IPB 190	COP - AL - IPB 300						
. 1	7	2.5	2.5						
2	15	3.2	3.2						
3	20	3.5	3.5						
4	25	3.7	3.7						
5	30	4	4						

Table 4.19: COPhp at different temp. In the range  $\{15^{\circ}C - 55^{\circ}C\}$ 



Figure 4.17: COPhp variation with temperatures for the range  $(15^{\circ}C - 55^{\circ}C)$ 

 $COPhp = 0.0635T + 2.1482 \tag{4.6}$ 

Hence from equation (4.6) respective COPhp for average, minimum and maximum daily temperatures were determined as shown in the Table 4.20

(1	(15°C - 55°C) RANGE FOR THE MONTH OF NOVEMBER 2006							
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.		
01/11/06	20.1	17.4	15.3	3.25	3.12	3.42		
02/11/06	23.0	17.5	12.0	3.26	2.91	3.61		
03/11/06	23.8	17.7	11.3	3.27	2.87	3.66		
04/11/06	20.0	17.6	15.5	3.27	3.13	3.42		
05/11/06	15.6	13.1	8.2	2.98	- 2.67	3.14		
06/11/06	16.8	12.1	8.3	2.92	2.68	3.22		
07/11/06	20.9	12.1	4.7	2.92	2.45	3.48		
08/11/06	19.6	13.1	8.5	2.98	2.69	3.39		
09/11/06	21.8	13.8	7.0	3.02	2.59	3.53		
10/11/06	21.5	14.8	7.6	3.09	2.63	3.51		
11/11/06	21.4	15.7	9.0	3.15	2.72	3.51		
12/11/06	21.6	15.7	9.0	3.15	2.72	3.52		
13/11/06	23.3	16.6	9.4	3.20	2.75	3.63		
14/11/06	23.1	17.4	9.5	3.25	2.75	3.62 ;		
15/11/06	20.6	15.9	11.7	3.16	2.89	3.46		
16/11/06	21.0	14.0	7.5	3.04	2.62	3.48		
17/11/06	23.6	14.6	5.0	3.08	2.47	3.65		
18/11/06	23.6	16.2	9.5	3.18	2.75	3.65		
19/11/06	22.4	15.6	9.2	3.14	2.73	3.57		
20/11/06	22.1	14.3	5.2	3.06	2.48	3.55		
21/11/06	21.3	13.7	6.4	3.02	2.55	3.50		
22/11/06	21.0	13.6	7.1	3.01	2.60	3.48		
23/11/06	21.4	13.7	6.5	3.02	2.56	3.51		
24/11/06	23.3	13.8	6.6	3.02	2.57	3.63		
25/11/06	24.0	14.5	4.3	3.07	2.42	3.67		
26/11/06	22.7	14.4	6.0	3.06	2.53	3.59		
27/11/06	23.8	13.4	7.0	3.00	2.59	3.66		
28/11/06	24.6	14.6	7.5	3.08	2.62	3.71		
29/11/06	24.8	15.6	4.8	3.14	2.45	3.72		
30/11/06	21.4	14.3	6.2	3.06	2.54	3.51		

Table 4.20: COPhp for min., average and max. temp. for Nov. range (15°C - SS<sup>2</sup>C )

(15°C - 55°C) RANGE FOR THE MONTH OF DECEMBER 2006								
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.		
01/12/06	20.2	14.1	8.6	3.04	2.69	3.43		
02/12/06	21.4	12.8	6.5	2.96	2.56	3.51		
03/12/06	19.0	11.3	4.6	2.87	2.44	3.35		
04/12/06	18.0	11.2	5.7	2.86	2.51	3.29		
05/12/06	18.8	11.7	4.5	2.89	2.43	3.34		
06/12/06	18.2	11.5	5.0	2.88	2.47	3.30		
07/12/06	19.5	1 <b>I.O</b>	5.0	2.85	2.47	3.39		
08/12/06	19.8	11.6	5.5	2.88	2.50	3.41		
09/12/06	17.0	1 I.O	5.0	2.85	2.47	3.23		
10/12/06	18.0	11.6	7.0	2.88	2.59	3.29		
11/12/06	21.5	12.1	7.0	2.92	2.59	3.51		
12/12/06	17.0	11.8	6.6	2.90	2.57	3.23		
13/12/06	19.0	15.0	IO.0	3.10	2.78	3.35		
14/12/06	21.0	13.2	7.4	2.99	2.62	3.48		
15/12/06	17.0	13.7	IO.0	3.02	2.78	3.23		
16/12/06	18.5	11.5	5.5	2.88	2.50	3.32		
17/12/06	21.0	11.9	4.5	2.90	2.43	3.48		
18/12/06	20.5	12.2	6.0	2.92	2.53	3.45		
19/12/06	20.5	12.8	6.5	2.96	2.56	3.45		
20/12/06	21.5	13.3	6.5	2.99	2.56	3.51		
21/12/06	22.0	15.1	9.1	3.11	2.73	3.55		
22/12/06	16.5	14.6	3.3	3.08	2.36	3.20		
23/12/06	13.2	11.1	6.5	2.85	2.56	2.99		
24/12/06	19.8	10.2	4.5	2.80	2.43	3.41		
25/12/06	18.5	11.2	4.5	2.86	2.43	3.32		
26/12/06	12.3	11.4	9.5	2.87	2.75	2.93		
27/12/06	8.5	6.7	5.0	2.57	2.47	2.69		
28/12/06	12.0	7.9	3.0	2.65	2.34	2.91		
29/12/06	15.9	7.2	-I.O	2.61	2.08	3.16		
30/12/06	17.0	9.8	4.0	2.77	2.40	3.23		
31/12/06	15.1	10.4	6.0	2.81	2.53	3.11		

Table 4.21: COPhp for max., average and min. temp. for Dec. for the range  $(15^{\circ}C - SS_{\circ}C)$ 

(15°C - 55°C) RANGE FOR THE MONTH OF JANUARY 2007								
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.		
01/01/07	17.5	8.6	2.4	2.69	2.30	3.26		
02/01/07	18.4	10.1	4.8	2.79	2.45	3.32		
03/01/07	16.8	12.5	8.4	2.94	2.68	3.22		
04/01/07	17.4	13.0	7.4	2.97	2.62	3.25		
05/01/07	15.7	13.6	12.2	3.01	2.92	3.15		
06/01/07	15.1	11.4	6.6	2.87	2.57	3.11		
07/01/07	14.6	11.1	7.3	2.85	2.61	3.08		
08/01/07	16.9	8.8	2.5	2.71	2.31	3.22		
09/01/07	16.6	9.7	3.0	2.76	2.34	3.20		
10/01/07	16.1	14.0	12.6	3.04	2.95	3.17		
11/01/07	15.6	14.0	12.7	3.04	2.95	3.14		
12/01/07	15.6	13.0	8.5	2.97	2.69	3.14 <		
13/01/07	16.6	8.8	1.9	2.71	2.27	3.20		
14/01/07	17.5	9.9	4.1	2.78	2.41	3.26		
15/01/07	16.8	10.7	5.0	2.83	2.47	3.22		
16/01/07	17.8	10.8	4.6	2.83	2.44	3.28		
17/01/07	19.8	11.9	5.8	2.90	2.52	3.41		
18/01/07	18.5	10.4	3.4	2.81	2.36	3.32		
19/01/07	16.8	11.0	5.2	2.85	2.48	3.22		
20/01/07	14.8	12.4	9.0	2.94	2.72	3.09		
21/01/07	15.7	12.8	8.9	2.96	2.71	3.15		
22/01/07	18.7	9.8	3.1	2.77	2.35	3.34		
23/01/07	18.0	11.1	4.5	2.85	2.43	3.29		
24/01/07	19.0	13.9	6.7	3.03	2.57	3.35		
25/01/07	19.0	13.7	6.6	3.02	2.57	3.35		
26/01/07	18.8	11.8	5.2	2.90	2.48	3.34		
27/01/07	18.8	11.3	4.6	2.87	2.44	3.34		
28/01/07	16.7	10.9	5.4	2.84	2.49	3.21		
29/01/07	14.2	9.6	5.5	2.76	2.50	3.05		
30/01/07	15.7	9.6	4.4	2.76	2.43	3.15		
31/01/07	15.4	8.9	2.0	2.71	2.28	3.13		

Table 4.22: COPhp for max., average and min. temp. for Jan. for the range  $(15^{\circ}C - 55^{\circ}C)$ 

(15°C - 55°C) RANGE FOR THE MONTH OF FEBUARY 2007							
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.	
01/02/07	16.4	11.0	4.0	2.85	2.40	3.19	
02/02/07	15.9	13.5	7.6	3.01	2.63	3.16	
03/02/07	14.0	12.6	10.9	2.95	2.84	3.04	
04/02/07	14.4	10.7	7.3	2.83	2.61	3.06	
05/02/07	13.7	9.1	5.7	2.73	2.51	3.02	
06/02/07	12.6	8.1	4.7	2.66	2.45	2.95	
07/02/07	14.6	8.4	2.9	2.68	2.33	3.08	
08/02/07	15.7	9.9	4.4	2.78	2.43	3.15	
09/02/07	16.7	14.4	8.7	3.06	2.70	3.21	
10/02/07	16.9	13.3	10.0	2.99	2.78	3.22	
11/02/07	17.4	11.0	4.9	2.85	2.46	3.25	
12/02/07	18.7	13.1	6.5	2.98	2.56	3.34	
13/02/07	17.4	12.8	7.9	2.96	2.65	3.25	
14/02/07	18.7	13.1	8.6	2.98	2.69	3.34	
15/02/07	15.9	11.9	8.3	2.90	2.68	3.16	
16/02/07	17.7	12.0	6.9	2.91	2.59	3.27	
17/02/07	17.8	13.8	7.0	3.02	2.59	3.28	
18/02/07	17.9	16.1	14.8	3.17	3.09	3.28	
19/02/07	19.4	12.9	7.3	2.97	2.61	3.38	
20/02/07	17.8	12.7	7.4	2.95	2.62	3.28	
21/02/07	18.9	16.1	13.3	3.17	2.99	3.35	
22/02/07	19.2	14.1	10.0	3.04	2.78	3.37	
23/02/07	18.5	13.5	9.4	3.01	2.75	3.32	
24/02/07	19.4	14.9	9.2	3.09	2.73	3.38	
25/02/07	17.3	13.7	9.9	3.02	2.78	3.25	
26/02/07	18.6	14.5	11.7	3.07	2.89	3.33	
27/02/07	17.4	13.3	10.3	2.99	2.80	3.25	
28/02/07	18.7	12.8	7.0	2.96	2.59	3.34	

Table 4.23: COPhp for max., average and min. temp. for Feb. for the range  $(1s_0c - ss_0c)$ 

(15°C - 55 °C) RANGE FOR THE MONTH OF MARCH 2007							
DATES	TMAX.	TAVG.	TMIN.	COP AVG.	COP MIN.	COP MAX.	
01/03/07	19.3	14.3	10.4	3.06	2.81	3.37	
02/03/07	19.8	14.5	10.4	3.07	2.81	3.41	
03/03/07	20.7	15.2	9.8	3.11	2.77	3.46	
04/03/07	20.4	14.2	8.5	3.05	2.69	3.44	
05/03/07	20.4	15.4	12.8	3.13	2.96	3.44	
06/03/07	19.8	14.0	11.4	3.04	2.87	3.41	
07/03/07	18.5	12.0	6.7	2.91	2.57	3.32	
08/03/07	19.3	12.1	5.7	2.92	2.51	3.37	
09/03/07	20.8	13.8	8.2	3.02	2.67	3.47	
10/03/07	20.2	13.3	6.5	2.99	2.56	3.43	
11/03/07	20.0	17.6	12.2	3.27	2.92	3.42,	
12/03/07	21.6	15.2	9.8	3.11	2.77	3.52	
13/03/07	19.4	13.7	8.6	3.02	2.69	3.38	
14/03/07	13.4	9.3	6.3	2.74	2.55	3.00	
15/03/07	12.8	7.0	3.1	2.59	2.35	2.96	
16/03/07	18.2	10.8	5.4	2.83	2.49	3.30	
17/03/07	16.7	12.4	6.5	2.94	2.56	3.21	
18/03/07	19.6	12.7	7.3	2.95	2.61	3.39	
19/03/07	19.7	13.8	7.1	3.02	2.60	3.40	
20/03/07	18.4	14.0	8.2	3.04	2.67	3.32	
21/03/07	19.9	17.0	10.5	3.23	2.81	3.41	
22/03/07	20.5	15.0	8.0	3.10	2.66	3.45	
23/03/07	21.4	18.0	16.8	3.29	3.22	3.51	
24/03/07	19.4	15.0	12.4	3.10	2.94	3.38	
25/03/07	20.4	,14.1	7.9	3.04	2.65	3.44	
26/03/07	19.4	13.1	8.4	2.98	2.68	3.38	
27/03/07	20.1	13.9	8.7	3.03	2.70	3.42	
28/03/07	20.6	14.1	7.7	3.04	2.64	3.46	
29/03/07	19.4	14.0	8.2	3.04	2.67	3.38	
30/03/07	19.6	14.3	8.1	3.06	2.66	3.39	
31/03/07	19.2	14.6	10.5	3.08	2.81	3.37	

Table 4.24: COPhp for max., average and min. temp. for March. For the range  $(15^{\circ}C - 55^{\circ}C)$ 

Below are the graphs showing the relationship between the respective COPhp and the dates.



Figure 4.18: COPhp based on average daily temperatures for the range  $(15^{\circ}C - SS^{\circ}C)$ 







Figure 4.20: COPhp based on maximum daily temperatures for the range  $(15^{\circ}C - 55^{\circ}C)$ 



Figure 4.21: COPhp based on minimum, average and maximum daily temperature

### 4.5 Payback Analysis

The Electricity Authority of the northern Cyprus issues its bills based on a bi- monthly basis. Charges are said to be incremental, That is to say, the cost per kWh of electricity

consumed increases with consumption. Although northern Cyprus power stations are fossils - fuels driven, as such there is what is called a fuel - adjustment surcharge. This is in accordance with the prevailing cost of oil, and is passed onto customers based on a per - kWh basis. Appendix 3.1 provide the 2016 northern Cyprus electricity bills. For our own case we consider the minimum value i.e. lkWh is to 0.44 Turkish Lira.

Consider the one unit of the heat pump i.e. 190-liter capacity for hot water supply under the following range of temperatures i.e.  $(15^{\circ}C - 45^{\circ}C), (15^{\circ}C - 55^{\circ}C)$  and  $(15^{\circ}C - 60^{\circ}C)$  respectively.

## 4.6 Unit with 190 Liters Capacity

The energy consumed by electrical heater and that by heat pump are calculated for each of the range of the temperatures under this unit as shown below.

$$W_1 = mC_P \,\Delta T \tag{4.7}$$

Where m = is the mass of water in kg (190liters ~ 190kg),

CP= specific capacity of water 4.186kJ/kg K,

t/T = is the change in temperature between the surrounding temperature and the condensing temperature i.e.  $t_1T = (45 + 273) - (15 + 273) = 30K$ 

$$W_1 = 190 \times 4.186 \times (318 - 288)$$
$$= 190 \times 4.186 \times 30$$
$$W_1 = 23860.2 \ k]$$

And the corresponding energy consumed by the heat pump is calculated by

where 
$$=\frac{W_1}{COP} = \frac{23860.2}{3.42} = 6976.67k]$$

Similarly to calculate the energy consumed by electrical heater  $W_2$  for the range of temperature (15°C - 55°C) it follows the same footprint with the first calculation above i.e.

$$W2 = mCp! T$$
  
W2 = 190 x 4.186 x (328 - 288)

$$W_2 = 190 \times 4.186 \times 40$$
  
 $W_2 = 31813.6 \ kJ$ 

And the corresponding energy consumed by the heat pump for the same range of temperatures is calculated by

$$W_{hp2} = \frac{W_2}{COP} = \frac{31813.6}{3.00} = 10604.53$$
k]

Now to calculate the energy consumed by electrical heater W<sub>3</sub> for the range of temperature  $(15^{\circ}C - 60^{\circ}C)$  it follows the same footprint with the second calculation above i.e.

$$l_1T_3 = (333 - 288) = 45^{\circ}C$$
  
 $W_3 = MC_P \Delta T$   
 $W_3 = 190 \times 4.186 \times 45$   
 $W_3 = 35790.3 \ kl$ 

And the corresponding energy consumed by the heat pump for the same range of temperatures i.e.  $(15^{\circ}C - 60^{\circ}C)$  is calculated by

$$Whp_3 = \frac{W3}{COP} = \frac{35790.3}{2.59} = 13818.65k$$
]

To compare the costs when an electric water heater is used in heating water and that when a heat pump system is used for the same purpose and for the same period of time let us make an analysis from the calculated values obtained for  $W\iota$ , W<sub>2</sub>, W<sub>3</sub> respectively.

Now consider them one after the other to see how much it will cost for either the electric water heater or the heat pump water heater system.

But  $W_1 = 23860.2 \ k$  which equal to 6.633 *kWh*. Also from Appendix 3.1 *lkWh* = 0.44 *TL* i.e. for each kilowatt hour of electricity consumed.

Therefore,

$$6.633kWh \times 0.44TL = 2.9186TL$$
 Per day.

Therefore, if we consider heating water for 5months, with 30days in each of the months, we have a total of 150days hence,

 $150 \times 2.9186TL = 437.79TL$  Per year with electrical heater.

Now consider the use of heat pump to do the same job and assuming the unit is to be run once daily for 5months period, noting that the calculated SCOP for the range of temperature  $(15^{\circ}C - 45^{\circ}C)$  is 3.42

Then,

#### 437.79TLj342 = 128.0ITL Peryearwithheatpump

So the benefits of using the heat pump over the electrical heater to heat the water is given below

$$437.79TL - 128.0ITL = 309.78TL$$

This simply means that the system has to be run for about 19 years for it to pay back for the unit price which is approximately 5927TL.

Also  $W_2 = 31813.6 \ k$  which equal to 8.844 kWh. and from Appendix 3.1, lkWh = 0.44TL i.e. for each kilowatt hour of electricity consumed.

Therefore

8.844kWh 
$$\times$$
 0.44TL = 3.891TL Per day with electrical heater

Therefore, 5months with 30days in each of the months, we have a total of 150days.

Hence,

150 X 
$$3.891TL = 583.72TL$$
 Per year with electrical heater

Now for heat pump to do the same job and for a 5months period, note that the SCOP obtained for the range of temperature  $(15^{\circ}C - 55^{\circ}C)$  is 3.00

Then,

$$583.72TLj300 = 194.57TL$$
 Per year with heat pump

So the benefits of using the heat pump over the electrical heater is given below

$$583.72TL - 194.57TL = 389.1STL$$

This means that the system has to be run for about 15 years for it to pay back for the unit price which is approximately 5927TL.
Similarly  $W_3 = 35790.3 \ k$  which equal to 9.95 kWh. Also from Appendix 3.1,  $1kWh = 0.44 \ TL$  i.e. for each kilowatt hour of electricity consumed.

Therefore,

$$9.95kWh \times 0.44TL = 4.378TL$$
 Per day.

Therefore, for 5months period assuming 30days in each of the months, we have a total of 150 days then,

150 x 4.378TL = 656.7TL Per year with electrical heater

With heat pump and for 5months period, recall that the SCOP for the range of temperature  $(15^{\circ}\text{C} - 60^{\circ}\text{C})$  is 2.59

Then,

#### 656.7TLj259 = 253.55TL Peryearwithheatpump

So the benefits of using the heat pump over the electrical heater is given below

$$656.7TL - 253.55TL = 403.15TL$$

Meaning that the system has to be run for about 14.5 *years* for it to pay back for the unit price which is approximately 5927TL.

For heat pump to do the same job and assuming the unit to work for a 5months duration, with the SCOP obtained for this range of temperature  $(15^{\circ}C - 45^{\circ}C)$  is 3.42

Then,

695.24TL/3.42 = 202.12TL Per year with heat pump

So the benefits of using the heat pump over the electrical heater is given below

695.24TL - 202.12TL = 489.12TL

This simply means that the system has to be run for about 12 *years* for it to pay back for the unit price which is approximately 5927TL.

#### CHAPTERS

### RESUL TS AND DISCUSSION

### 5.1 Results

Table 5.1 gives a tabular result of the method suggested for estimating the maximum possible COPhp by employing a number of cycles of heat pumps connected in series in an N- stages, notice that TH is to be changing continuously while maintaining a constant TL.

,			-1	
Staze number	TL[KJ	Tu[KJ	COP for each cycle	COP for N- stage
1	280	289	32.11	32.11
2	280	290	29.00	30.48
3	280	291	26.45	29.01
4	280	292	24.33	27.68
5	280	293	22.54	26.47
6	280	294	21.00	25.37
7	280	295	19.67	24.36
8	280	296	18.50	23.43
9	280	297	17.47	22.58
10	280	298	16.56	21.78
11	280	299	15.74	21.05
i 12	280	300	15.00	20.36
13	280	301	14.33	19.73
14	280	302	13.73	19.13
15	280	303	13.17	18.57
16	280	304	12.67	18.04
17	280	305	12.20	17.55
18	280	306	11.77	17.08
19	280	307	11.37	16.64
20	280	308	11.00	16.23
11202 <b>21</b> 4284	280	309	10.66	15.83
22	280	310	10.33	15.46
2 <b>3 1</b> 88	280	311	10.03	15.10
24	280	312	9.75	14.77
25	280	313	9.48	14.44
26	280	314	9.24	14.14
27	280	315	9.00	13.84
28	280	316	8.78	13.56
29	280	317	8.57	13.30
30	280	318	8.37	13.04
31	280	319	8.18	12.80
32	280	320	8.00	12.56
33	280	321	7.83	12.33
34	280	322	7.67	12.12
35	280	323	7.51	11.91
36	280	324	7.36	1171
37	280	325	7.22	11.52
38	280	326	7.09	11.33
39	280	327	6.96	11.15
40	280	328	6.83	10.98
41	280	329	6.71	10.81
42	280	330	6.60	10.65
43	280	331	6.49	10.49
44	280	332	6.38	10.34
45	280	333	6.28	10.19

Table 5.1: Summary table for overall COPhp and individual COPhp

Based on the assumptions used here, the difference between the final and the initial water tank temperature is  $45^{\circ}$ C and since we consider the value of *llT* to be equal to  $1^{\circ}$ C, then we have 45 number of heat pumps to be connected in N- stages.

The evaporator temperature was kept constant while varying the condenser temperatures as seen in the Table 5.1 above

The COPhp for both individual cycles of heat pumps and that of the overall stages of the heat pumps were determined and were shown graphically.



Figure 5.1: Comparism between individual COPhp and the overall COPhp with TH

And it is shown clearly in Figure 5.1 that employing number of heat pumps in an N-stages improves the COPhpvalue much higher than if the heat pumps were not. This shows that employing more cycles of heat pumps gives a more precise value of the COPhp,

As shown in the Figure 5.2, is a comparism between the COPhp of a vapor compression refrigeration cycle and that of the Reversed Carnot cycle. At different condenser temperatures and the evaporator temperature been constant.





Figure 5.2: Comparism between COPhp for IVCRC and RCC

The COPhp for the reversed Carnot cycle is always greater than that of the vapor compression refrigeration cycle because it is completely reversible cycle. Additionally the COPhp here is a function of the evaporator temperature and the condenser temperature and hence the COPhp increases sharply with evaporator temperatures, especially at high condenser temperatures, and it reduces as the condenser temperature increases but the effect tends to be marginal at low evaporator temperatures.

Although to build and operate reversed Carnot cycle in reality is impossible due to the difficulties in the compression of liquid-vapor at the compressor in which the reciprocating compressors especially high speed ones easily get damaged with the present of liquid in the vapor, and also the expansion process i.e. using turbine to extract work during the isentropic expansion of liquid refrigerant which is uneconomical and affect the blades of the turbine. But still the reversed Carnot cycle set the highest theoretical COPhp and is used as reference against which the real cycles are compared.

RATED COP	3.60
MIN. SCOP	3.09
AVG. SCOP	3.42
MAX. SCOP	3.77

Table 5.2: Rated COPlip and Cal.S	COF
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As shown in the Table 5.2 are the rated COPhp for a specific unit of heat pump for the range of temperature of  $(15^{\circ}\text{C} - 45^{\circ}\text{C})$  as declared by the manufacturer at a particular surrounding temperature of 15°C, and the calculated SCOP that was obtained from our previous calculations with several different temperatures as shown in Figure 5.3 below



Figure 5.3: Rated COPhp and calculated SCOP

The above chart is comparing the rated COPhp and the calculated SCOP for the given range of temperature as stated above.

It is obvious that the surrounding temperature plays a significant role towards these results. The SCOP for the minimum and the average daily temperatures are less than that of the rated COP, and the SCOP for the maximum daily temperatures is higher than the rated COP, all this variations are as a result of the surrounding temperatures i.e. which for both the minimum and the average daily temperatures are mostly less than 15°C which affect the SCOP value for this two categories of temperatures hence given a value less than that of the rated COPhp which is declared with 15°C surrounding temperature.

Furthermore, for the maximum daily temperatures that are higher than 15°C provides an SCOP greater than the rated COPhp simply due to the temperature difference i.e. mmAimum daily temperatures are greater than 15°C

Hence the higher the surrounding temperature the higher the COPhp and as well the SCOP and the more efficient the heat pump will be, as well the less running cost of the unit will be and vise-versa.

#### 5.2 Payback outcome

Range	Energy consumed with electrical heater (W)	Energy consumed with Heat pump(Wh)	Cost per year with Electrical heater	Cost per year with Heat Pump	Benefits of using Heat Pump	Payback period
15°C - 45°C	23860.2kJ	6976.7kJ	437.79TL	128.0ITL	309.78TL	19years
15°C- 55°C	31813.6kJ	10604.5kJ	583.72TL	194.57TL	389.15TL	15years
15°C-60°C	35790.3 kJ	13813.6kJ	656.70TL	253.55TL	403.15TL	14.5years

Table 5	.3: Water	heating	cost p	er year
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It is seen clearly that for each category and at different ranges of temperature the cost per year for heating water with electrical heater is much higher almost three times more than that when a heat pump is used, as such using the heat pump to heat the water provides so much benefits as provided in Table 5.3 above.

Although the payback period seems to be much longer especially in the case of the first and second i.e. 19years and 15years and even though it could be possible to run the unit for even more than such a years especially with proper installation, since a refrigerator last for several years operating without failing, and that the heat pump works as a refrigerator but in reversed which follow almost the same footprint with the refrigerator.

Additionally, with the new versions of heat pumps that have a better controls that are more robust than the old versions, it could be economically wise employing the use of the heat pump for heating water and possibly space conditioning since most of the people that uses heat pumps, used it for both purposes, and with heat pumps used in homes for either water heating or for both including space conditioning.

The environment is less polluted since the air is continually extracted and been used by the heat pump to generate the heat that will be used in heating water or space condition.

# CHAPTER6 CONCLUSION

#### 6.1 Conclusions

Heat pump water heating system is an essential energy saving mechanism that save a lot of energy and cost as compared to electric resistance water heater that consumes more than three times the energy used by the heat pump systems as the unit COPhp is declared to be 3.6.

A method was suggested in other to estimate the maximum possible COPhp of a heat pump water heaters by employing a number of series connection of heat pumps in an N-stage, since using the reversed Carnot cycle as a heat pump to heat water have difficulties, therefore TH has to be changing continuously so as to heat the water to the required temperature.

Reversed Carnot cycle operating as a Carnot heat pump is used in determining the coefficient of performance of a heat pump and compared with that of the vapor compression refrigeration cycle and was found to have a higher COPhp,

Seasonal coefficient of performance SCOP was determined by the Northern Cyprus meteorological data for Nicosia 2006/2007 based on the daily maximum, average and minimum temperatures and compared with that of the specified unit as declared by the manufacturer, which shows that the surrounding temperature has a significant effect towards the COPhp value, the higher it becomes the more precise the COPhp and as well the SCOP and vise- versa.

Finally, the cost of heating water per year with heat pump and that with electrical heater were analyzed, and it was clearly seen that using the heat pump provide additional benefits of saving costs as it is much lesser as compared to the electrical heater costs. Even though the payback period is a bit longer, but with proper installation and maintenance the unit could run for even more years.

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# APPENDICES

# APPENDIXI

# THEMODYNAMICS TABLES

# Table 1.1: Properties of saturated refrigerant 134a (liquid- vapor) temperature table

#### TABLE A-10

$bar = 0.1 \text{ MPa}$ $= 10^2 \text{ kPa}$		Specific Volume m <sup>1</sup> /kg		Internal Energy kl/kg		Enthalpy ~!{k~			Enl kj/i		
Temp. 'C	Press, bar	Sat. Liquid vi × 10 <sup>3</sup>	Sat. Vapor	Sat. Liquid	Sat. Vapor	Sat. Liquid	Evap.	Sat. Vapor	Sat. Liquid	Sat. Vapor	Temp
-40	0.5164	0 7055	0.2640	- 0 QL	000	0.00			പ്പോല് പോല് പോല് പോല് പോല് പോല് പോല് പോല	ag San san san san san san san san san san s	
	0.6322	0 7112	0.3067	~0.04	204,45	0,00	222.88	222.88	0.0000	0.9560	41
- 12	0 7704	0 7173	0.2941	4,00	200.75	4./3	220.67	225.40	0.0201	0.9506	-31
~28	n 0305	0.777Z	0.2421	7.47	209.01	9.52	218.3/	227.90	0.0401	0.9456	-3
-76	1 0100	0.7265	0.2002	14.21	243 43	14.37	210,01	230.38	0.0600	0.9411	- 21
	S. S	- <b>***</b>	0,1004	10.73	212.42	ID-BZ	214,80	231.62	0.0699	0.9390	-2
-111.	1.1160	0.7296	0.1728	19.21	213.57	19.29	213.57	232.85	0.0798	0.9370	- 2
,,22	1.2192	0.7328	0.1590	21.68	214.70	21.77	212.32	234.08	0.0897	0.9351	2
-W	1.3299	0.7361	0,1464	24.17	215.84	24.26	211.05	235.31	0.0996	0.9332	20
-18	1.4483	0.7395	0.1350	26.67	216.97	26.77	209.76	236.53	0.1094	0.9315	-18
16	1.5748	0.7428	0.1247	29,18	218.10	29.30	208.45	237.74	0.1192	0.9298	- 10
-12	1.8540	0.7498	0.1068	34,25	220.36	34.39	205.77	240,15	0,1388	0.9267	- t
-8	2.1704	0.7569	0.0919	39.38	222.60	39.54	203.00	242.54	0,1583	0.9239	
~4	2.5274	0.7644	0.0794	44.56	224.84	44.75	200.15	244.90	0.1777	0.9213	4444
Q	2,9282	0.7721	0.0689	49.79	227.06	50.02	197.21	247.23	0,1970	0.9190	•
4	3.3765	0.7801	0.0600	55.08	229.27	55.35	194.19	249.53	0.2162	0.9169	
S	3.8756	0.7884	0.0525	60.43	231.li6	60.7::1	191.07	251.80	0.23Str	0.9150	
n	4.4291i	0.7971	0.0460	65.83	233.63	66.18	18.7.8	254.03	0.2545	0.9132	1
1(,	S,0416	0.8062	0.0405	71.29	235,78	71.69	184.52	256 ·il2	0.2735	0.9116	16
20	5.7160	0.81S7	O.(13:18	76.80	237.91	77.26	181.09	286.36	0.2924	0.9102	20
24	6.4566	0.8257	0.03t7	62;37	240.01	82.90	177.S~	260.1 <b>.</b> IS	0.3113	0.9089	24
26	6.8530	0.8309	0.0298	85.18	241.05	B5.75	175.73	261.48	0.3208	0.9082	26
28	7.2675	0.8362	0.0281	88.00	242.08	88.61	173.89	262.50	0.3302	0.9076	28
30	7.7006	0.8417	0.0265	90.84	243.10	91.49	172.00	263.50	0.3396	0.9070	30
32	8.1528	0.8473	0.0250	93.70	244.12	94.39	170.09	264.48	0.3490	0.9064	32
34	8.6247	0,8530	0.0236	96.58	245.12	97,31	168.14	265.45	0.3584	0.9058	34
36	9.1168	0.8590	0.0223	99.47	246.11	100.25	166,15	266.40	0.3678	0.9053	36
38	9.6298	0.8651	0.0210	102.38	247.09	103,21	164.12	267.33	0.3772	0.9047	38
40	10.164	0.8714	0.0199	10S.30	248.06	106.19	162.05	268,24	0.3866	0.9041	40
42	10,720	0.8780	0.0188	108.25	249.02	109.19	159.94	269,14	0.3960	0.9035	42
44	11.299	0.8847	0.0177	111.22	249.96	112.22	157.79	270.01	0.4054	0.9030	44
48	12.526	0.8989	0.0159	117.22	251,79	118,35	153,33	271.68	0.4243	0.9017	4R
52	13.851	0.9142	0.0142	123.31	253.55	124,58	148.66	273.24	0.4432	0.9004	57
56	15.278	0.9308	0.0127	129.51	255.23	130.93	143.75	274.68	0.4622	0.8990	56
60	16.813	0.9488	0,0114	135.82	256.81	137.42	138.57	275.99	0.4814	0.8973	60
70	21.162	1.0027	0.0066	152.22	260.15	154.34	124.08	278.43	0.5302	0.8918	70
60	26.324	1.0766	0.0064	169.86	262.14	172.11	106,4'1	279,12	0.58111	0.8827	80
90	32.1135	1.1949	0.0046	189.82	261.34	193.69	82.63	276.12	0.6380	0.8685	90
1(10	39.742	1.51\4)	0.00n	218.60	248 49	221 74	31) 40	250.13	0.7106	0.8117	100

≡ ~

Table	<b>1.2</b> Properties	of superheated	refrigerant	134a vapor table
-------	-----------------------	----------------	-------------	------------------

Pressure Conversions: 1 bar = 0,1 MPa = 10<sup>2</sup> kPa

TABLE A-12

ŗ	v	- 40	Jı	S	v	41	h	S
.:C	<u>1</u> 111;/k1:		ffJ/,t\11,	k/lf <g td="" ●)<<=""><td>m<sub>3</sub>/Btg,,</td><td>.kJf.ikg</td><td></td><td>'9/kg , 1</td></g>	m <sub>3</sub> /Btg,,	.kJf.ikg		'9/kg , 1
		9 = 8.0 b.	ar = 0.80 N	iPa	p	= 9.0 bai	= 0.90 MI	<sup>&gt;</sup> a
	******	( <i>Y<sub>sal</sub> =</i>	= 31.33°C)	green valationere	******	(T <sub>set</sub> ==	35.53°C)	5 / 7 / 6 IV 6 IV 6 IV 6 I 8 / 8 / 8
Sat,	0.02547	243.78	264.15	0.9066	0.02255	245.88	266.18	0.9054
40	0,02691	252.13	273.66	0.9374	0.02325	250.32	271.25	0.9217
5U	U.U2846	261.62	284.39	0.9711	0.02472	260.09	282.34	0.9566
60	0.02992	271.04	294.98	1.0034	0.02609	269.72	293.21	0.9897
70	0.03131	280.45	305.50	1.0345	0.02738	279.30	303.94	1.0214
80	0.05264	289.89	316.00	1.0647	0.02861	288.87	314.62	1.0521
90	0.03393	299.37	326.52	1.0940	0.02980	298.46	325.28	1.0819
100	0.03519	308.93	337.08	1.1227	0.03095	308.11	335.96	1.1109
110	0.03642	318.57	347.71	1.1508	0.03207	317.82	346.68	1.1392
120	0.03762	328.31	358.40	1.1784	0.03316	327.62	357,47	1.1670
130	0.03881	338.14	369.19	1.2055	0.03423	337.52	368.33	1.1943
140	0.03997	348,09	380.07	1.2321	0.03529	347.51	379.27	1.2211
150	0.04113	358.15	391.05	1.2584	0.03633	357.61	390.31	1.2475
160	0.04227	368.32	402.14	1.2843	0.03736	367.82	401.44	1,2735
1/0	0.04340	378.61	413.33	1.3098	0.03838	378.14	412.68	1.2992
180	0.04452	389.02	424.63	1.3351	0.03939	388.57	424.02	1.3245
		• = 10.0 b	ar = 1.00 N	Pa		= 12.0 bar	======================================	no este terre considerativa Al
		(T =	39.39°C)			(T. = 4	6.32°C)	
bat,	0.02020	247.77	267.97	0.9043	0.01663	251.03	270.99	0 0023
40	0.02029	248.39	268.68	0.9066				~,~~~
5,0	0.02171	258.48	280.19	0.9428	0.01712	254.98	275.52	0.9164
60	0.02301	268.35	291.36	0.9768	0.01835	265.42	287.44	0.9827
i'O	0.02423	278.11	302.34	1.0093	0.01947	275.59	298.96	0.9868
80	0.02538	287.82	313.20	1.0405	0.02051	285.62	310.24	U1192
90	0.02649	297.53	324.01	1.0707	0.02150	295 59	321.39	1.0503
00	0.02755	307.27	334.82	1.1000	0.02244	305,54	332.47	1.0804
10	0.02858	317.06	345.65	1.1286	0.02335	315.50	343.52	1.1096
i!ıtı	0.02959	326.93	356.52	1.1567	0.0.2423-	325.51	354.58	1 1151
30	0.03058	336.88	367.46	1.1841	0.czsoa	.3~.sa	365.68	1.1660
40	0.03154	346.92	378.46	1.2111	0.02592	3.115.73	376.83	1.1933
50	0.03250	357.06	389.56	1.2376	0.02674	ISS 95	388.04	1 2201
the second se	0.03344	367.31	400.74	1.2638	0.ô~754	16()27	399.33	1.2465
60	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	・ストリー ほうしい ほしいちょう いちがく	したべんにはある 感知的なな 分析 静力	网络哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈哈	ประเทศสาร์สมบัตร์สาวสารีเสียง	and a state of the state of the	0.67.57.57.57.57.57.57.57.57.57.57.57.57.57	
60 70	0.03436	377.66	412.02	1,2895	Q.02834	376,69	410.70	1.2724

devery environment and the second second

#### 944 Tables In SI Units

#### TABLE A-II

laster	Draccure Conversions:	Properlies of Saturated Refrigerant 134a (Llqufd-Vapor): Pressure Table
1		A star and a star a st

	bar = 0.1 M = 10 <sup>2</sup>	(Pa)	Specific m <sup>3</sup>	Volume /kg	Inleri,al	Energy [ <i>l</i> .~	1-14-14-14-1-1-1-1-1-1-1-1-1-1-1-1-1-1-	Enthalpy k]/kg		Ent kJ/k	ropy g · K	
te j	Become	1	Sat.	Sat.	Sat.	Sal.	Sat.		Sat.	Sat.	Sat.	
Net al total	har	remp.	Liquio	Vapor	Uqi.nd	V~por	hquiicl	Evap.	Vapoi	Liquid	Vapor	Press.
0.000	(11	1.07	1.19.00 KM	1:n	,			1168	h <sub>k</sub>	\$r	Ś <sub>z</sub>	bar
al a second		~;1.07	0,70!>7	0.3100	3.41	206,12	3.46	221.27	W1,72	0.0147	0,9520	0.6
Digman.	1.0		0./184	0.2366	10.111	20!M6	10.47	217,92	228.39	0.0440	0.9447	0,8
10110	1.0 +1	20.43	0.725B	{1,1917	16.22	212.18	16.29	21S.O(,	2:ili,M	() <b>,06</b> iil	0,9:'195	1.0
000000	11	-,22.30	0.73;?:;1	0.1614	21,23	214.SO.	21,32	212S4	233,86	0.0879	0.9354	1.Z
1000	1.4		0./381	0.1395	2!>.66	216.52	25.71	210.27	236,04	0.10S5	0.9322	1.4
ALC: NO.	1.6	-15.62	0.7435	0.1229	-29.66	218.31	29,78	208.19	237 97	0.1211	0.9295	16
citiza)	UI	-12.73	0,7485	0,1098	33.)1	21!',1,94	33.45	206.26	239 71	0.13\$2	0.9273	1.0 † a
00700	2.0	-10.09	0.7532	0.0993	36.69	221,43	36.84	204.46	241 30	0.1302	0.0273	10
X	2.4	-5.37	O.U,18	0.0834	42.77	22/1,07	.t12.95	201.14	21.14.09	0 m0	0.9233	2 1
10000	za	-1.23	0,7697	(MJ719	48.18	:i:26,3:8	iiıM9	198.13	246.52	0.1911	0.9197	2.8
DR.	3.2	2.4.11.	10,''1770	0.0632	53.06	22.11	43 31	105 35	218 66	0.2000	0.0177	-2.0
	3.6	5.84	0.7839	0.0564	57.54	2)~il~	57.82	193,35	240.00	0.2089	0,9177	3,2
	s.e	8,93	o.7904	0.0509	61/i9	23i 91'i	67.00	190.32	25 38	0.2251	0.9100	3.0
and and	5.0	15,74	o.acss	0.0409	70.93	 M	71 33	184 74	256.07	0.2:. 199	0,9145	4.0
strates	6.0	21.58	0.8196	0.0341	78.99	238.74	79.48	179 71	250.07	0.272,)	0,9117	5.0
	7.0	1.6.72	0 11°m1	0.0202	86.10	14140	041-70	1 71317	259.19	0.2777	0.9097	0.0
COLOR.	8.0	31.33	0.8454	0.0292	02 75	141A2	01 40	1./!W/	261.85	0.3242	0,9080	7.0
2012	9.0	35.53	0.8576	omu.	92.75	015.76	93,42	1/0./3	264.15	0.3459	0.9066	8.0
Sec.	rn.o	39.39	0.8695	0.0202	104.42	245.88	99.56	166.62	266.18	0.36\$6	0,9054	9.0
	12.0	46.32	0.8872	0.0202	fü'i 60	2.4/.1/	105,2!>	162.68	267.97	0.3838	0.9043	10.0
al and a second			0.5524	0.0100	101.07	231,0)	115.70	155.25	270.99	0.4164	0,9023	12.0
2000	14.0	52.113	0.9159	0.0140	123.98	253.74	125.26	148.14	27).40	0.44.53	OS10-03	Ilı.O
History	16.0	\$7.92	0.9:392	o.om	nısı	256.00	134.,01	141.)1	27\$.)3	0,4714	0,89.82	16.0
(CARACINE)	18.0	62,91	0.9631	0.0105	140.t,9	257.88	142,22	1)4.60	276.83	0.4954	Q.89.59	18,()
CONC.	:100	67.119	0.9878	0.00.9)	148.02	259.41	149,j!9	127.95	277.')4	0.5178	0.8934	20.0
	25.0	77.S9	1.0562	0.0069	16S.48	261.84	16~.12	111.06	279,17	O!S687	0.885,)	25.0
	30.0	86.22	1.1416	0.0ô;S:'1	181,88	262.16	1s5,30	92.71	278.01	0,61S6	0.8735	30.0
<b>B</b> <sub>jin</sub>	lenininadore sun	1976 Collective and the defin	internet and an overally	Nig 440 and a statem	ARKARADINTONES.CO	จจัดสารสารสาร	NATA MALANA AND AND AND AND AND AND AND AND AND	alanderadar orreiteradar	Managang kang sang ka	and the second		terrational terration

 $v_1 = (\text{table value})/1000$ 

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### APPENDIX2

# ALDEA HEAT PUMP TECHNICAL SPECIFICATIONS

# Figure 2.1: Aldea Heat pump

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ALDEA HAVADAN SUYA ISI POMPASI ISI POMPALI BOYLER -- ----AL- IPB 190 AL-IPB300 KULLANIM KILAVUZU -----

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Model	Ebatlar (mm: Dxy)	Net/brüt a ırlıt	Güc Kayna 1	
AL-IPB190 ¢1568x1640		941110	220-240V-1 ph-50Hz	
AL-IPB300	¢1650x1,920	123,1150	220	

	-1-1-

Model		······		100	
Çaltı rna rnodu	J		AL-1,PS 190		
Çāli ma o:itam,i sicakli i			Ekonomi	E-isitici	
Çıkı suyu sicaklı j			-Y-43		
Güç kayna ı			Varsayılan 55" <b>C</b> ,38•c - 7,1100		
Depolama boy	utu	F11-V-112	1-220- 240-50		
	Kapasite		1	190	
Su isitma	Penfomi katsavisu (PK)	fum/////	1.5	3.00	
	Mak, akim		3.6	1.00	
Ortanı sıcakJı	I	A	3.4	13.0	
	Ebatlar (DxH)	-L mm	-30-43		
ünite	Ambalai (WxH: Q)		(i)568x1640		
	Net/brüt a u1/k	nnn Ira	675x1715:><690		
Gürültü seviyes			941#10		
So utucu tipi /r	niıctarn		41		
So utucu tasar	nrni	.kg	R134af0.95		
basıncı		MPa	2.611.2		
Depo tasarmn	liasmci	MPa	0 15-1 0		
KismatipJ			Eleklı'onıik ger	le me vatli	
Sistem koruması			TC01, TC02, PTvallı,otoniatik buzçözm,e, a iri yük konumasısıcaklı i. elektrik kaça ina kar i koruma		
Hava akı ı (filtre elekli)		m::;111	218(2	02/178	
	Model		PJ125G1C-4DZDE		
	Тір		Döner		
	Marka		GMCC		
	Kapasite	Btu/h	47	740	
Kompresör	Giri	kŴ	0.515		
	Nominal akını (RLA)	А	2.32		
	KilitU rotor Amp (LRA)	А		15	
	Termal koruyucu		125		
	Kapasilör	μF	25		
	So⊢utucu ya	mi		400	
Fan motor	Model		YDK1	YDK12~6A	
	Marka		welling		
	Giri	W	28		
	Hız	r/dak.	900/8151680		
	Yalıtım sınıfı		F	3	
	Giineriliksinifi		IPX4		
	Giri	W	28		
	Çiki	W	0		
	Nominal akım	A	0.12		
	Kapasitör	I.IF	1.2		
	1				

## Table 2.1: AL- IPB 190 technical specification

Model			AL-IPB 300			
OÇalı rna modu			Ekoiriomi	E-isitici		
Çalı ma oıtam,ı sıcaklı ı		'0 <b>C</b>	-r43	-30- 43		
Çıkı suyu sıcaklı ı		ΰC	Varsavılan 55°C.38	"Qč - 60•c		
GiiÇ kayna ı		Ph-V-Hz	1-220 -240-50			
Depolama ebadı		L	300			
-	Kapasite	k	3.00	3.00		
Su isitma	Peiforiiians katsayisi (PK)	iMi/kW	3.60	1.00		
	Maks. akını	A	6.5	13.0		
Ortanı sıcaklı		ΪC	-30-43	1		
	Eballar (Dxf-1)	mm	(1)650)(1,92	20		
Oni~	Ambalaj {Vı/xl+l:-0)	mm	7501'2,150x780			
	Net/tırilta ırlık	k	123/150			
Gürültü seviyesi		dB{A}				
So utucu tipi/miktarı		k	R134a/1.2			
So utucu tasarım basıncı	io utucu tasarım basıncı		3.0/1.2			
Depo tasarım basıncı		MPa	1			
Kısma tipi			Elektrikli genle mevalfı			
Sistem koruması			TC01, TC02, PT valfı, otomatik buz <b>çö</b> zns a ın yük korumasısıcaklı ı. elektrik kaça ına kar ı koruma			
Hava akımı		ni•isaa.i	4141355/312			
	Model		RB233GRDC			
	Тір		Döner			
	Marka		Guangzhou Mitsubishi electric			
	Kapasite	aiuisaat	9500			
	Girdi	k	0.9			
Kompresör	Nominal akını {RLA}	A	4.1			
	Kilitli rotor Amp (LRA)	A	30			
	Termal koruyucu		115			
	Kapasilör		30			
	Krank kutusu	Ŵ	25			
	So utucu ya	m	440			
	Model	1	VD/60.0D			
Marka			YDK30-6R			

# Table 2.2: AL- IPB 300 technical specifications

## Table 2.3: AL-IPB 300 technical specifications

-	Girdi	1 T				
Fan motor	Hız		68			
	Valilimeruufi	rldak.	620/530/465			
	Cüvenlikeunfi		В			
	Suverink simil		IPX4			
	Konocilär	A	0.3			
	Kapasiloi	μF	2.5			
	Dfzisayisi		3			
	lup aralı ı(a}x dizi aralı ı {b)	mm	22x:19.05			
	Kanat mesafesi	mm	1.5			
Buharla tirici bobini	Kanat tipi (kod)		Hidrofilik alüminyum			
· · · · · · · · · · · · · · · · · · ·	Tüpün dı çapı ve tipi		8			
			ic Vida d i			
	Bobin uzun. x yüksek.	mm	482 ><852			
	Devre sayısı		4			
	Su giri i borusu	mm	DN20			
Su borusu hattı	Su çıkı ı borusu	mm	DN20			
	Drenaj borusu	mm	DN20			
	PT valf mafsalı	mm	DN20			
lsı e anjörü						
	Su giri i borusu	mm				
	Su çıkı i borusu	mm				
Güne ısısı e anjörü	ısı e anjörü					
	Dim.x Uzunluk	mm				
	Malı:. basınç	MPa	22x10000			
E-isitici	-ISITICI		0.7			
Sıcaksu randımanı		meisaat	3			
Yükleme Miktarı 20'/40'/40H		Poe	0.086			
ikiama1a.r:		1.69	21/47/47			

ALDEA Isi Pompasi Teknik El Kitabi-ISI POMPALI BOYLER

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 $1.\ Tl!SU<Dttlart.Oif \ \texttt{ota}/\texttt{c}\texttt{l}(\texttt{,}\ 15.1:\texttt{a}^*\texttt{C}\ (DBIWS),\texttt{gri}\ \bullet u \sim \ \texttt{sca1<lig}. \ 15'C, \texttt{c}\texttt{k}\texttt{l}\ SU-J \ \texttt{oos}/\texttt{c}\texttt{l}\texttt{g}\texttt{l}\texttt{l}(\texttt{,}\ 15.1:\texttt{a}^*C)$ 

 $\label{eq:art:ham-europerator} 2 \sim \mbox{ art:ham-europerator geli ~fl'mel{icin} de i tirifebirr. !fittenfaim lemas ına bakmılz. }$ 



Figure 2.2: AL- IPB 190 COP / Ambient temperature chart

Figure 2.3: AL- IPB 300 COP / Ambient temperature Chart

Model: AL-IPB 300



#### APPEND1X3

#### ELECTRICTY CONSUMPTION RATES

## Table 3.1: Electricity bill per kilowatt hour for Nicosia 2016

			Indenso Dusep	នាំបទ បទប្អូស្វាក	м уаршнадн.			
<b>T</b> arire Kod ve Tarife ismi Eshii Mał		u Ocfetler	Yeni Maktu	Yeni Maktu Ücretler **	TOKETIlı.!!)CıRETLIERI ESKi		Yeni Tatil&	jartı oram
	<u> </u>		October			-	,Ochimen	
U1 Geçici Akım Tarifesi	1			www.com.com.com.com	Her kWs için	0,98	0,98	0,00%
14 Geçici Akım Tarifesi II						0,87	0,87	0,00%
02 konut Tarifesi (8k 250 Kws için) Yoksul		16,95	16,95	12,00	Her kWs icin	0,25	0,20	-20,00%
02 konut Tarifesi (0- 250 Kws )	<u> </u>	16,95	16,95	12,00	Her kWs için	0,44	0,40	-9,09%
02 konut Tarifesi ( 251-500 Kws )		16,95	18,95	12,00	Her kWs icin	0,48	0,45	-6,25%
02 konut Tarifesi ( 501-750 Kws )		16,95	16,95	12,00	Her KWs için	0,52	0,49	-5,77%
02 konut Tarifesi (751 Kws üzeri)		16,95	16,95	12,00	Her kWs icin	0,54	0,52	-3,70%
		manatoria						
03 Tican Tanlo	Tek faz	18,17	18,17		Her kWs için	0,40	0,40	0,00%
	Çok faz	31,50	31,50					
Nd Tironi Tanifa	Hor KWA	7 00	7 00	· · · · · · · · · · · · · · · · · · ·	d Chillen	0.40	A 10	0.000
	Itala	1,00	1,00			0,40	0,90	0,00%
	11501				C. LANNIN	n'3a	0,38	0,00%
05 Endüstri Tarile	Tek laz	18 17	18 17		Line killin Join	0 X0	A . A	0.008/
	Cok faz	21 60	19,17		rusi nirrə içini	0,40	0,40	0,0070
	PANY set.	J. J	91,99					
06 Endüstri Tarile	Her KVA	7,00	7,00		1.Dilim	0.40	0.40	0.00%
	liçin				2.Dilim	0,39	0,39	0.00%
			20003040940092494094444444	and a constraint of the sector (devices)		- management again	and construction of the second se	and a subscription of the
06 (a) IEootistti Tartiii	Her KVA	3,50	3,50		1.Dilăm	0,40	0,40	0.00%
	için				2.Dilim	0,39	0,39	0,00%
		all and the second second second			and the other states and the states of the			
07 Iurl:1:11, lar.ml	Tek laz	18,17	18,17		Her kWs için	0,40	0,40	0,00%
	IÇok faz	31,50	31,50					
OB TuuilzmtuurHe	Mar KUA	7 66	7.00		d fullan		A 40	0.005
	inin		100		1. Dillion	0,40	0,40	0,00%
n an	In States and States and	NEW MARKEN PARTY AND	antistic discussion of the second		Provide State S		1,33	0,0078
09 Su Motorian	Tek fez	18 17	18 17		Hor Mile inin	n anl	01.0	0.00%
	Cok laz	21 60	21 50		ives nan e nyan	0,40	VINU	0,0076
	NOT YOR	01,001			·····	L		
10 Sokak İşıkları						0,45	0.435	-3.33%
							-1.57	
12 Savunma Tarifesi	21 D022004 8 01 NOT TO ADD ADD ADD ADD ADD ADD ADD ADD ADD AD	-			Her kWs için	0,45	0,435	-3,33%
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KKTC ELEKTRIK KURUMU 01 Nhum 2018 TARIHINDIEN ITIBAREN UYGULAMADAOLAN TARIFE ÜÇREn.ERI Bu tarihi uwudamada sadaca matuu bastara dati tutuu uutuutu

Kib, till Bitgi fikn Bitimi of Msim 2016

Fatura talebinde bulunan tüketiciler için almacak wıdı!Miltr,t,t
 Fatura talebinde bulunmayan tüketiciler için ulmıcınk muntu u,mıt

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