B.M. Salim
Engineering Technical College, Refrigeration & A/C Department, Northern Technical University Mosul, Iraq.
badranm2000@yahoo.com

I.F. Abdulqadir
Engineering Technical College, Refrigeration & A/C Department, Duhok Polytechnic University Duhok, Iraq
naqshabandi56@yahoo.com

F.M. Younis
Engineering Technical College, Refrigeration & A/C Department, Duhok Polytechnic University Duhok, Iraq
firasmahmood@yahoo.co.uk

Received on: 24/08/2016
Accepted on: 23/02/2017

Economic Feasibility Study of Modern and Conventional Central Heating Systems for Villa Located in Duhok City, Iraq

Abstract-*This research includes the evaluation of economic feasibilities based on the Iraqi's market cost by using three different types of central heating systems in a residential villa located in Duhok city / Iraq. It also compares between modern and conventional central heating systems. A life cycle cost analysis based on detailed heating and operation load profiles considered in this work. Initial, running and maintenance costs for three central heating systems examined for fifteen years as a working period. The used systems in this study were; modern central heating system (heat pump water heater system) and conventional central heating system (fuel oil hot water boiler system and electric hot water boiler system). Transfer function method with hourly analysis program platform (HAP4.9) used for estimation the heating loads within each zone of the project. The proposed technique of modern central heating system found to be more efficient for thermal and economic efficiencies and it uses an environmentally friendly refrigerant such as (R410A). It also works efficiently in severe cold climate with low temperature of (-20°C) in winter season. The results shows that the heat pump water heater central heating system is most efficient system, this system has provided an energy saving range up to 57.5% compared with electric hot water boiler system and 70.6% compared with fuel oil hot water boiler system.*

Keywords- *Central Heating Air Conditioning System, Life Cycle Cost Analysis, Initial Cost, Running Cost, Maintenance Cost.*

How to cite this article: B.M. Salim, I.F. Abdulqadir and F.M. Younis, "Economic Feasibility Study of Modern and Conventional Central Heating Systems for Villa Located in Duhok City, Iraq," *Engineering and Technology Journal*, Vol. 35, Part A, No. 7, pp. ٧٢٥-٧٣٦, 2017.

1. Introduction

Air conditioning system for residential building amortize up to 50% of electricity in many regions around the world [1]. However, the commercial building sector was responsible for 64% of electricity consumption [2]. Therefore, minimize energy consumption becomes the main target in designing new air conditioning systems. Moreover, Iraqi HVAC designers have come up with sustainable designs that lower energy use in residential or commercial buildings. However, a central heating system that saves operating costs usually requires a higher initial investment. In this case, engineers should decide whether it is worth paying the extra initial cost for a system that has lower operating cost [3]. Salim [4] showed that the total cost of two A/C systems (RAC & CAC) for residential apartment are equal after 20 months of the beginning run. Then after breaking point the total cost for CAC system began to decline, which indicates that there is saving in electric consumption. This presents a worthy cost over a period of ten years operation interval. Wang et al. [5] indicated that the low temperature radiant floor heating system is more suitable for natural gas condensing water boilers. It is also more comfortable, more economical, and can save more energy than other heating systems. Li et al. [6] pointed out that the composite energy heating systems has higher initial investment but lower operating costs, combined static payback period of comparison. The composite energy-heating mode has significant economic benefits as well as good prospect in market competitiveness. Shah et al. [7] submit the compares of life cycle influences for three residential heating and cooling systems over a thirty-five years study period of the systems at four locations in the United States. In Minnesota, Pennsylvania, and Texas, the heat pump has the highest impacts whereas in Oregon the heat pump has the lowest impacts.

The purpose of this work is to compare three different types of central heating systems, taking in to account the initial cost, maintenance and operating cost. The systems are Fuel oil hot water boiler system, Heat pump water heater system and Electric hot water boiler heating system, each central heating system is briefly described.

https://doi.org/10.30684/etj.35.7A.8
2412-0758/University of Technology-Iraq, Baghdad, Iraq

Moreover, the design and operation of mentioned systems presented in details. A residential building (Villa) as a model located in the Duhok city was selected to test the above mentioned systems, with daily operation period of 20 hours. In addition, the life cycle cost for these systems is analyzed and economically evaluated based on detailed load estimation, initial cost, maintenance cost and operating costs for 15 years period [8,9].

Nomenclature:
HAP: Hour Analysis Program
TFM: Transfer Function Method
FHWBs: Fuel Oil Hot Water Boiler System
HPWHs: Heat Pump Water Heater System
EHWBs: Electric Hot Water Boiler System
LIFE: Average Lifetime of Equipment
COP: Coefficient of Performance
A/C: Air Conditioning
HVAC: Heating, Ventilation & Air Conditioning
CAC: Commercial Air Conditioning
RAC: Residential Air Conditioning
DBT: Dry Bulb Temperature (ºC)
IC: Initial Cost ($)
OC: Operation Cost ($)
MC: Maintenance Cost ($)
3Ø: Three Phase
Qt.:Quantity
r: Discount Rate
$:US Dollar
ID: Iraqi Dinar
H:Height (m)
EQP: Equipment Price ($)
No.: Number of Items

2. Description the Project Sample with Heating Load Estimation

The sample of residential house considered in this study is villa, which consists of two floors with gross area of ground and first floor respectively as 370 m² and 329 m². The villa located in Duhok city / Iraq (36.820 latitude and 43.146 longitude), Figures (1-a) and (1-b) shows the architectural plan and result of heating load for ground and first floors. The central heating period for Duhok city, which has extremely cold, winter temperatures and wet climate covers 182 days approximately.

The indoor air conditions of dry bulb temperature and relative humidity are (24.2°C & 40%) respectively. The outdoor design temperature that used in this study at winter is (-6°C) dry bulb temperature and (-11°C) wet bulb temperature [10]. In this study, the transfer function method based on derivative of the heat balance that used within hourly analysis program (HAP v4.9) so as to estimate the heating load for each zone within the villa as shown in Table 1. The total heating load for ground and first floor are 23.9 kW and 27 kW respectively, Figure 2 shows flow chart that use to estimate heating load for each zone of the project. Roof construction consist of (Flat , 40-mm high density concrete shtyger, 70 mm dry sand, 150mm high density concrete and 10mm juss plaster) while walls construction consist of (15 mm cement plaster , 240 mm common brick and 15 mm juss plaster).

3. Description of the Types of Central Heating Systems

The second step after finalizing the heating load estimation for the project is choosing the appropriate central heating system that consumes lower running cost during fifteen years of running interval with giving easy facilities in installation, high efficiency and maintenance work in future. In this study, three different types of central heating system used as follows:

i. Fuel Oil Hot Water Boiler System (FHWBs).
ii. Heat Pump Water Heater System (HPWHs).
iii. Electric Hot Water Boiler System (EHWBs).

I. Fuel Oil Hot Water Boiler System (FHWBs)

Oil fuel boilers are pressure vessels designed to transfer heat produced by combustion to a fluid. In most boilers, the fluid is usually water in the form of liquid or steam. The firebox, or combustion chamber, of some boilers is also called a furnace. Excluding special and unusual fluids, materials, and methods, a boiler is a cast-iron, carbon or stainless steel, aluminum, or copper pressure vessel heat exchanger designed to burn fuels and transfer the released heat to water (in water boilers) [11]. A radiator unit is the heat distributing devices used in low temperature and water heating systems. They supply heat by a combination of radiation and convection and maintain the desired air temperature and/or mean radiant temperature in a space without fans [12]. The advantages of using oil central heating boiler as oil as a fuel tends to be truly efficient, the return cost is quite satisfactory. Additionally, the replacement of old boiler with some other new efficient model is very hassle free process. Figure 3 shows the schematic diagram of radiator units with two-pipe system. The fuel oil hot water central heating system design by using HVAC solution software that used to state the bill of quantity is shown in Table 2 [13]. The Figure 4 shows the water pipe design with radiator distribution that is used in this study.

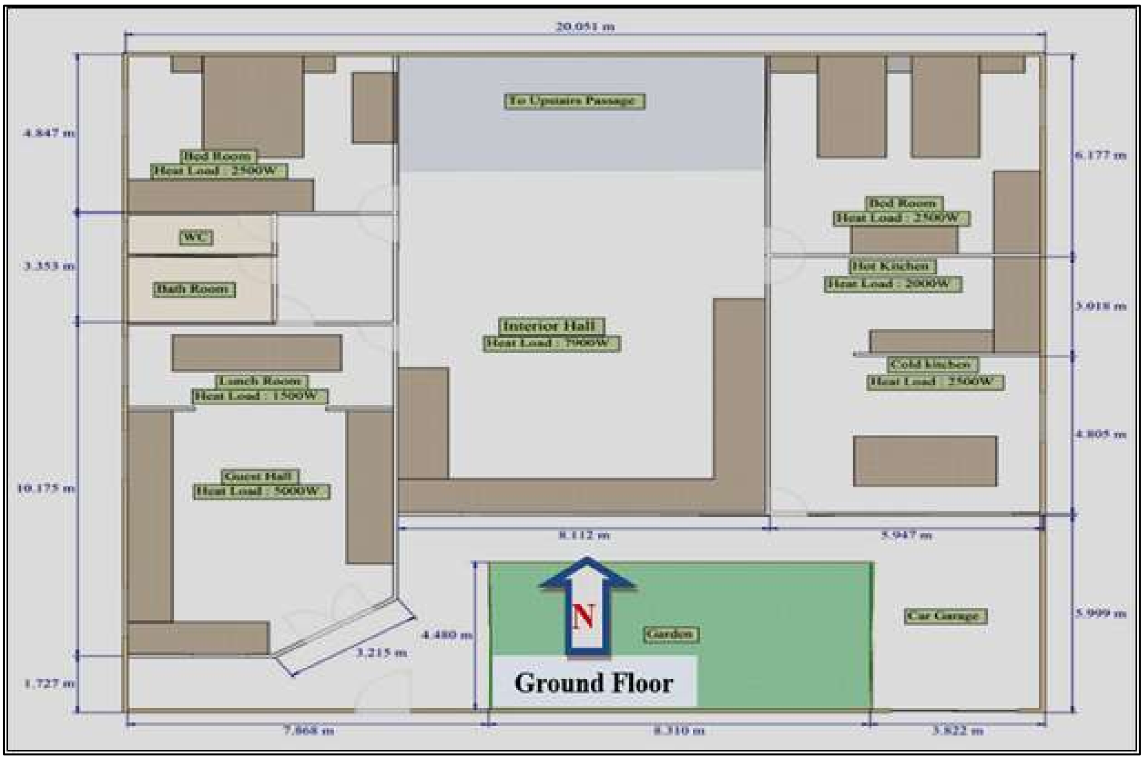

Figure 1-a: Details of Architectural Plan and Heating Load Values for Ground Floor of Villa

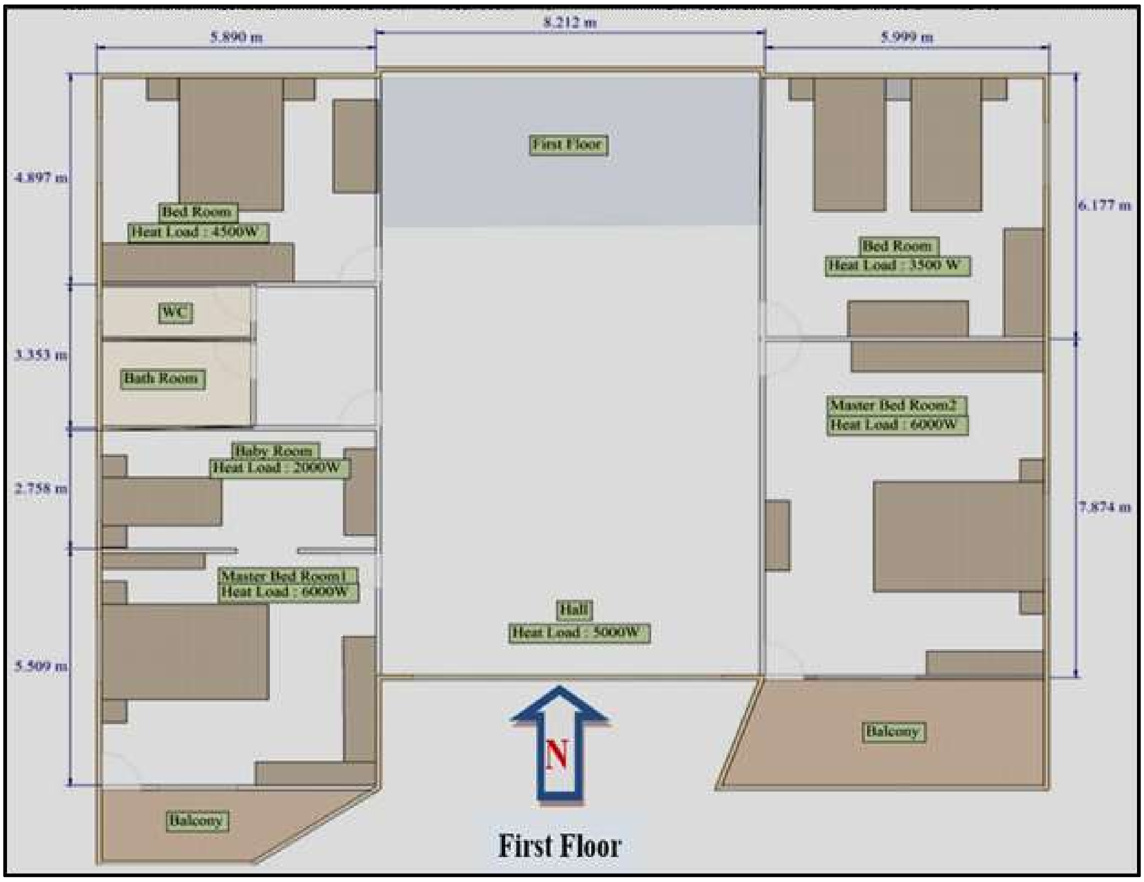

Figure 1-b: Details of Architectural Plan and Heating Load Values for First Floor of Villa

Table 1: Heat Load Values for each Zone in Ground and First Floor

Zone Description	Area (m²)	Height (m)	Heat Load (kW)
Ground Floor			
Main Hall	61.5	3.2	7.9
Bed Room (1)	37.2	3.2	2.5
Bed Room (2)	28.9	3.2	2.5
Hot Kitchen	17.7	3.2	2
Cold Kitchen	28.3	3.2	2.5
Guest Hall	38.4	3.2	5
Lunch Room	16.5	3.2	1.5
First Floor			
Hall	61.5	3.2	5
Bed Room (1)	33	3.2	3.5
Bed Room (2)	37	3.2	4.5
Baby Room	17.7	3.2	2
Master Bed Room (1)	32.5	3.2	6
Master Bed Room (2)	46	3.2	6

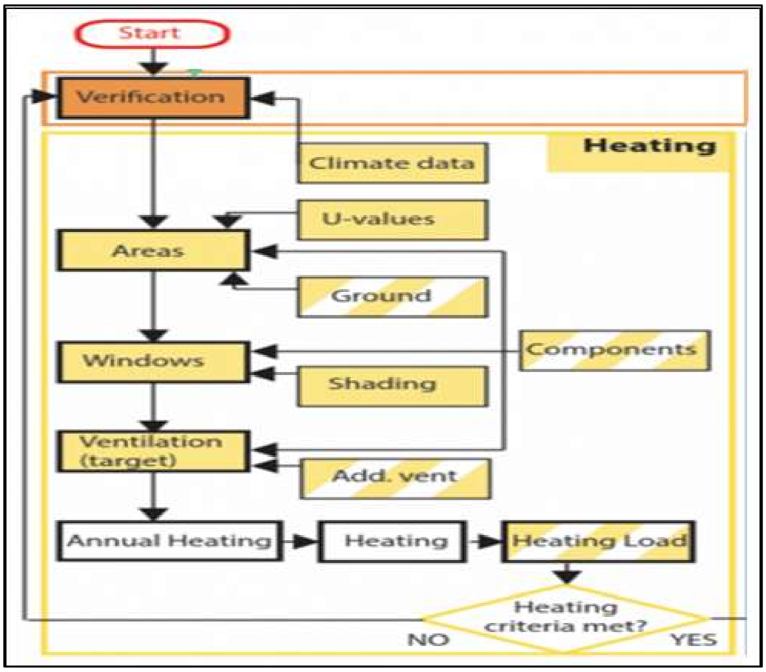

Figure 2: Heat Load Estimation Flow Chart

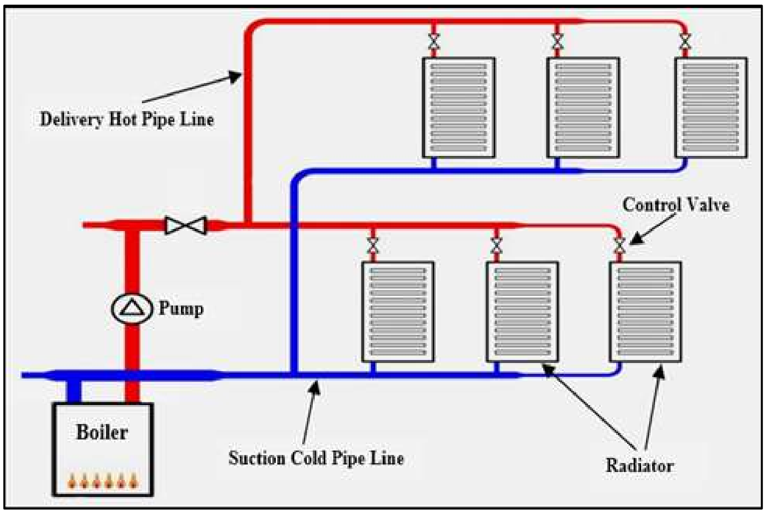

Figure 3: Details of Two Pipe Hot Water System

Table 2: Initial and Installation Cost of FHWB Central Heating System

Description of Items	Unit	Qt.	U. Price($)	T. Price($)
Fuel Oil Cast Iron Boiler Heating Capacity 26 kW (TR20).	No.	1	7,200	7,200
Fuel Oil Cast Iron Boiler Heating Capacity 30 kW (TR30).	No.	1	8,500	8,500
Panel Radiator Inline Unit 1500 W Capacity	No.	1	600	600
Panel Radiator Inline Unit 2000 W Capacity.	No.	2	650	1,300
Panel Radiator Inline Unit 2500 W Capacity.	No.	3	700	2,100
Panel Radiator Inline Unit 3500 W Capacity.	No.	1	750	750
Panel Radiator Inline Unit 4500 W Capacity.	No.	1	800	800
Panel Radiator Inline Unit 5000 W Capacity.	No.	2	900	1,800
Panel Radiator Inline Unit 6000 W Capacity.	No.	2	1,100	2,200
Panel Radiator Inline Unit 7900 W Capacity.	No.	1	1,200	1,200
Expansion Tank Capacity 38.8 Liter.	No.	2	700	1,400
Air Separator with Strainer.	No.	2	200	400
Black Steel Water Pipe 15mm Diameter with Installation.	m	160	40	6,400
Black Steel Water Pipe 20mm Diameter with Installation.	m	100	50	5,000
Black Steel Water Pipe 25mm Diameter with Installation.	m	110	60	6,600
Black Steel Water Pipe 32mm Diameter with Installation.	m	50	70	3,500
Balance &Automatic Valve Size 15mm with Installation	No.	10	100	1,000
Balance &Automatic Valve Size 20mm with Installation	No.	3	150	450
Check & Swing Valve Size 25mm &32m with Installation	No.	1	500	500
Water Pump Mount End Suction / Q=0.41 L/S & H=26m.	No.	1	850	850
Water Pump Mount End Suction / Q=0.47 L/S & H=25m.	No.	1	1,000	1,000
Another Cost for Complete Installation	---	---	3,000	3,000
Total Cost of Initial and Installation				**56,550 $**

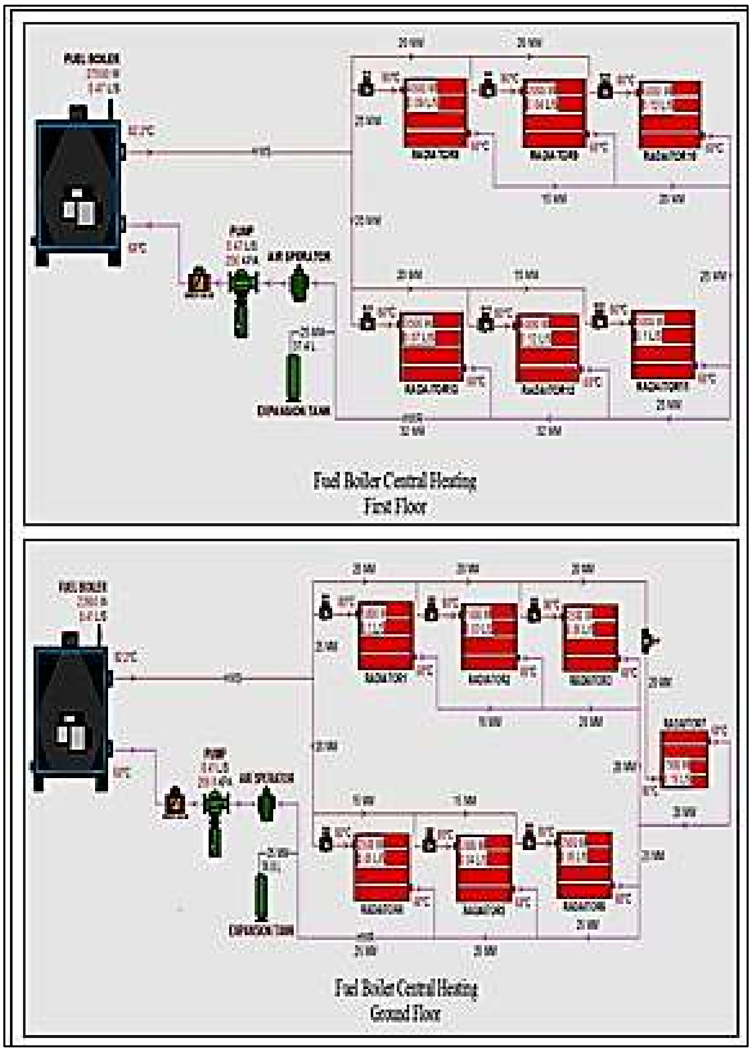

Figure 4: FHWB Central Heating System Design and Radiator Distribution for Ground and First Floor of Villa

II. Heat Pump Water Heater System (HPWHs)

During the last two decades, radiant floor heating applications have increased significantly. In the 1950s and 60s, floor heating installations using steel or copper pipes were installed in middle Europe. Unfortunately, at this time, buildings were not well-insulated so very high floor temperatures were required to heat the houses, which gave floor heating a bad reputation. Then, at the end of the 1970s, the introduction of plastic pipe for floor heating prompted the system to become standard, especially in many countries in the world. Today, plastic pipes of the PEX-type are mainly used. Floor heating is mostly used in residential buildings [14]. Modern underfloor heating systems use heat pump as heat source for water flowing within plastic pipes to heat the floor. Electric heating elements or hydraulic piping can be cast in a concrete floor slab ("poured floor system" or "wet system"). They can also be placed under the floor covering ("dry system") or attached directly to a wood sub floor ("sub floor system" or "dry system"). Even in the cold months the heat pump water heater system will still work up to (-20°C). They do require electricity to run but the heat they are extracting from the air is being renewed as a natural process. Heat pumps work much more efficiently at a lower temperature than a standard boiler system, so they are more suitable for under floor heating systems or larger radiators, which give out heat at lower temperatures over longer periods. Figure 5 shows the schematic diagram of heat pump water heater system with under floor radiant temperature. The heat pump water heater system design by using heat cad software that used to state the bill of quantity is shown in Table 3. Figure 6 shows the under floor heating system design [15].

III. Electric Hot Water Boiler Heating System (EHWBs)

This type of central heating system is the same as fuel hot water boiler system except the source as this type depends on electricity for source heat of water. The advantages of the electric hot water heater include quicker heating and safety ratings that are higher as well as it may have a slightly longer lifespan than other units. This largely depends on local water quality and owner maintenance. While the disadvantage occurs when there is an unlikely event of energy failure or energy cut. Figure 7 shows the hot water central heating system design by using HVAC solution software that is used to state the bill of quantity as shown in Table 4.

4. Costs Analysis of Central Heating Systems and Results

The overall cost analysis for central heating system that used in the residential building (Villa) classified as initial cost, operation cost and maintenance cost, that will be incurred over the lifetime of A/C system should be taken into account.

I. Initial Cost

The total initial cost of central heating systems includes purchasing and installation cost. The details within Tables 2, 3 and 4 show the estimated initial costs for three different types of central heating system, Fig.(8) shows the initial cost result for three types of A/C systems. It is seen that the initial cost for the HPWHs is 20.2% lower than EHWBs and 28% lower than FHWBs.

II. Operation Cost

The running energy for heat pump hot water system and electric hot water oiler system depend on the electrical energy while the oil fuel hot water boiler system use the fuel for operation the system. The estimated electric and fuel power consumption depend on the book data for each central heating system to run the different types of central heating systems [16,17]. The electricity tariff is the sale price of the electrical unit to calculate the total cost per month for residential [18]. The net operating time of the residential is twenty hours per one day for all days of year. Equation (1) illustrates the amount of electricity running cost for one day only Table 5 shows the amount of energy cost for different type of central heating systems. Figure 9 shows the running cost per one year for different system. It is seen that the annual cost for HPWH is 57.8% lower than EHWBs and 70.6% lower than FHWBs. On the other hand, the annual maintenance of EHWBs is 8.5% lower than HPWHs and is 26.5% lower than FHWBs as illustrated in Table 5 and Figure 10.

Note: 1$=1250ID

Running Cost per Month ($) = Amount of Energy (kW) × Operating Time (20 Hours per Day) × 30 (Days) × Electricity Tariff ($/kW.Hr) **(1)**

III. *Maintenance Cost*

Maintenance costs include all planned equipment maintenance, such as cleaning, replacement and repair. It depends on age of the system and the length of time of operation of central heating system [19]. The cost that the customer pays annually for maintenance the central heating system is expressed by eq. (2). Table 6 shows the maintenance cost for each central heating system. Figure 10 shows the maintenance cost per one year for different central heating system [20]. It is clear that HPWHs has an approximate running cost save for 15 years life cycle of 57.5% ($71.73\times10^3$$) compared with EHWBs, and 70.6% ($125.9\times10^3$$) if compared with FHWBs.

$$MC = \frac{0.5 \times EQP}{LIFE} \quad (2)$$

5. Life Cycle Cost Analyses of Air Conditioning System

A life cycle cost analysis carried out to analyze the total cost as initial, operating and maintenance costs for different types of air conditioning systems. The air-conditioning systems has fifteen years as life cycle and the present-worth cost technique used to evaluate the central heating system. It is also use to examine total costs. Equation (3) shows the life cycle cost equation [21] and Figure 11 shows the life cycle cost of central heating system for fifteen years. It is obvious that it found that the HPWHs has significant advantages compared to other two systems. This is because this system offers the lowest running and total costs compared to other central heating systems. In addition, the HPWHs works extremely at low temperatures reach up to (-20°C). It can be equipped with modern technologies as smart integrated controls, variable speed drives, ozone friendly refrigerant and flexible operation.

$$LCC = IC + \sum_{n=1}^{n=15} \frac{(OC + MC)}{(1+r)^n} \quad (3)$$

Based on the instructions of the ministry of electricity, there is negligence of the discount rate on electric power consumption in Iraq and then the equation (3) becomes:

$$LCC = IC + \sum_{n=1}^{n=15}(OC + MC) \quad (4)$$

6. Conclusions

This paper conducts a study to analyze three different central heating systems. These systems examined in a villa located in Duhok city northern part of Iraq. The transfer function method used to calculate the heating load in each zone, with the aid of HAP software. Fuel oil hot water boiler system FHWBs, heat pump water heater system HPWHs and Electric hot water boiler heating system EHWBs examined and compared taking into account the initial and running costs for 15 years working time. It is concluded that HPWHs saves significant amount of energy of about 57.5% and 70.6% if compared with EHWB and FHWB respectively. HPWHs works on the lowest running cost when compared with other systems. In contrast, EHWBs has the lowest maintenance cost if compared with the other ones. Likewise, EHWBs has operation cost lower than FHWBs for 15 years period. It is inferred that HPWHs has superior advantages in both running and initial cost when compared with its competitive.

Figure 5: Description of the Elements of Heat Pump Water Heater System

Table 3: Initial and Installation Cost of HPWH Central Heating System

Description of Items	Unit	Qt.	Unit Price($)	Total Price($)
Heat Pump Water Heater System Capacity 36 kW.	No.	2	10,500	21,000
Domestic Hot Water Cylinder	No.	2	1,000	2,000
Control Kit	No.	2	600	1,200
Under Floor PEX Pipe with Installation	m	1,150	10	11,500
Another Cost for Complete Installation	---	---	3,000	5,000
Total Cost of Initial and Installation				**40,700 $**

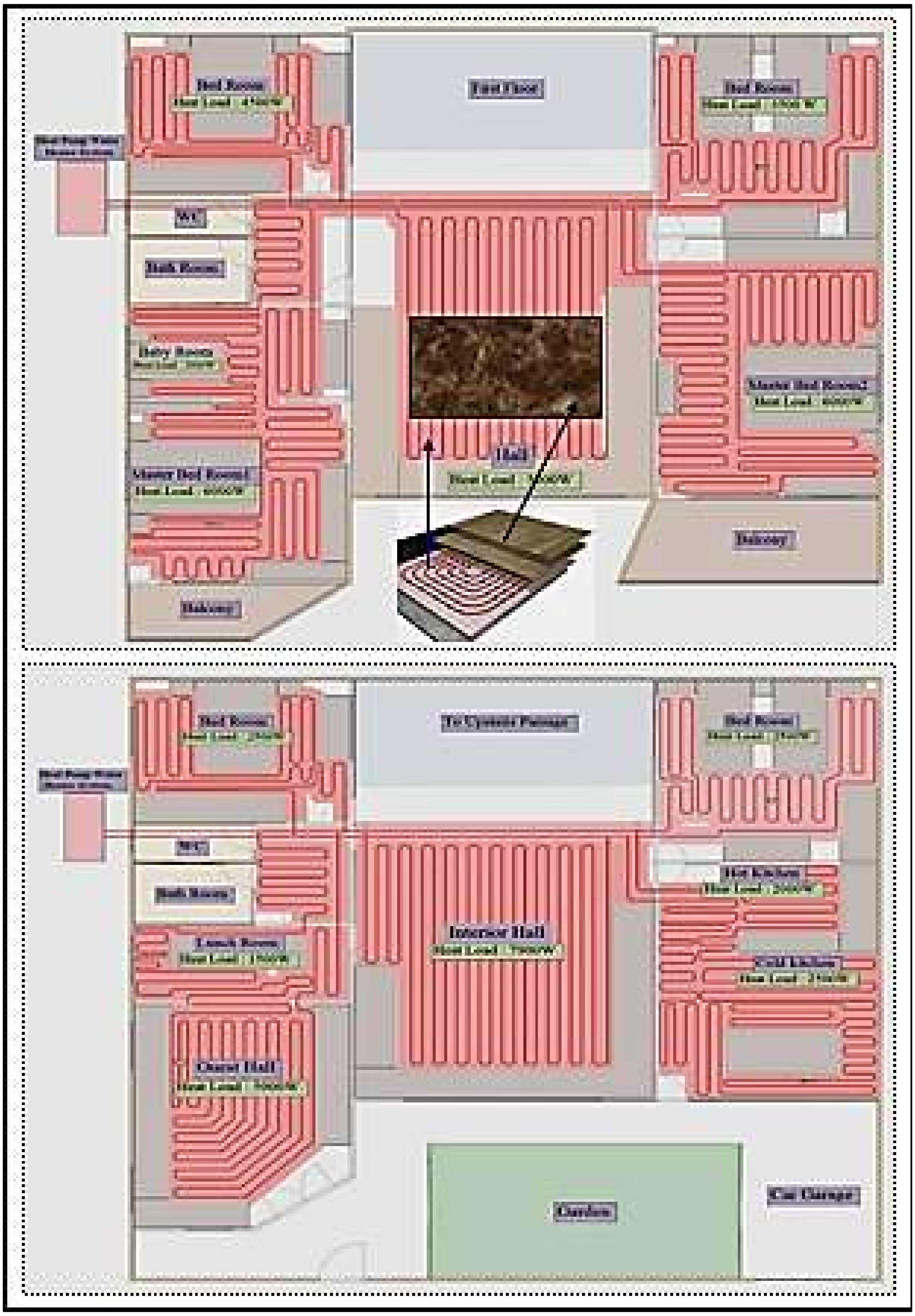

Figure 6: HPWH Central Heating System Design and under Floor Radiant Temperature Distribution for Ground and First Floor of Villa

Table 4: Initial and Installation Cost of EHWB Central Heating System

Description of Items	*Unit*	*Qt.*	*U. Price($)*	*T. Price($)*
Electric Hot Water Boiler Heating Capacity 25 kW.	No.	1	4,200	4,300
Electric Hot Water Boiler Heating Capacity 30 kW.	No.	1	4,800	5,800
Panel Radiator Inline Unit 1500 W Capacity	No.	1	600	600
Panel Radiator Inline Unit 2000 W Capacity.	No.	2	650	1,300
Panel Radiator Inline Unit 2500 W Capacity.	No.	3	700	2,100
Panel Radiator Inline Unit 3500 W Capacity.	No.	1	750	750
Panel Radiator Inline Unit 4500 W Capacity.	No.	1	800	800

Panel Radiator Inline Unit 5000 W Capacity.	No.	2	900	1,800
Panel Radiator Inline Unit 6000 W Capacity.	No.	2	1,100	2,200
Panel Radiator Inline Unit 7900 W Capacity.	No.	1	1,200	1,200
Expansion Tank Capacity 38.8 Liter.	No.	2	700	1,400
Air Separator with Strainer.	No.	2	200	400
Black Steel Water Pipe 15mm Diameter with Installation.	m	160	40	6,400
Black Steel Water Pipe 20mm Diameter with Installation.	m	100	50	5,000
Black Steel Water Pipe 25mm Diameter with Installation.	m	110	60	6,600
Black Steel Water Pipe 32mm Diameter with Installation.	m	50	70	3,500
Balance &Automatic Valve Size 15mm with Installation.	No.	10	100	1,000
Balance &Automatic Valve Size 20mm with Installation.	No.	3	150	450
Check & Swing Valve Size 25mm with Installation	No.	1	200	200
Check & Swing Valve Size 32mm with Installation	No.	1	300	300
Water Pump Mount End Suction / Q=0.41 L/S & H=26m.	No.	1	850	850
Water Pump Mount End Suction / Q=0.47 L/S & H=25m.	No.	1	1,000	1,000
Another Cost for Complete Installation	---	---	3,000	3,000
Total Cost of Initial and Installation				**50,950 $**

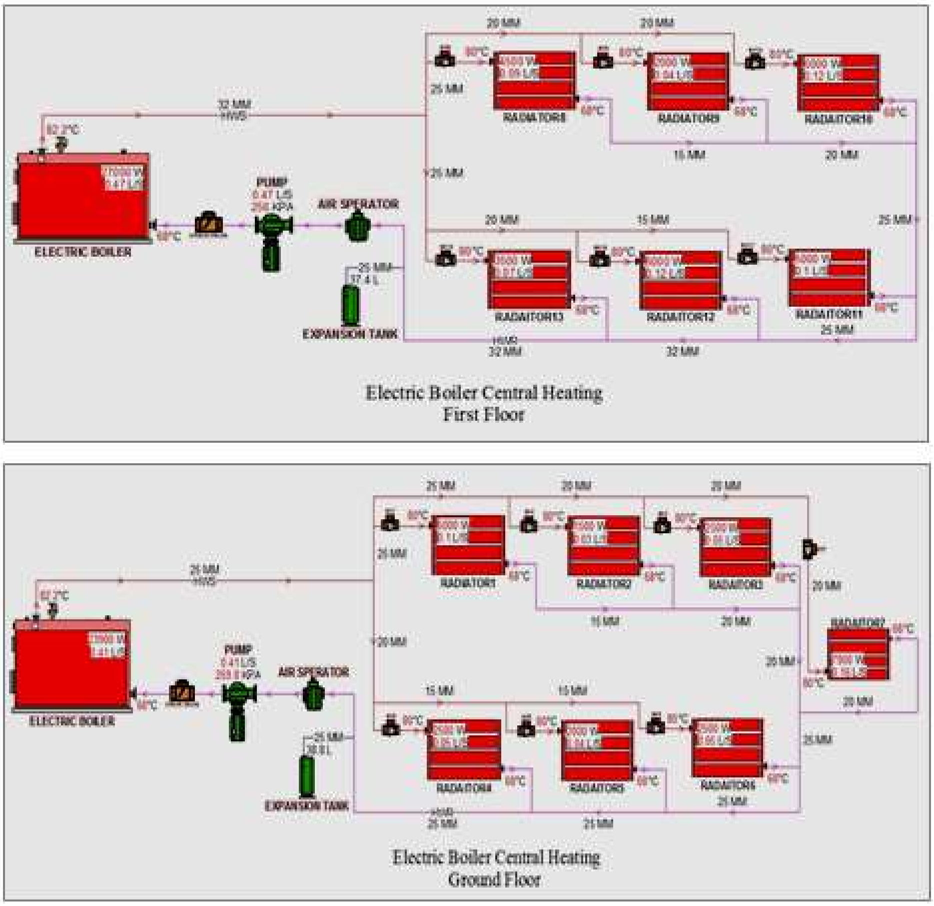

Figure 7: EHWB Central Heating System Design and Radiator Distribution for Ground and First Floor of Villa

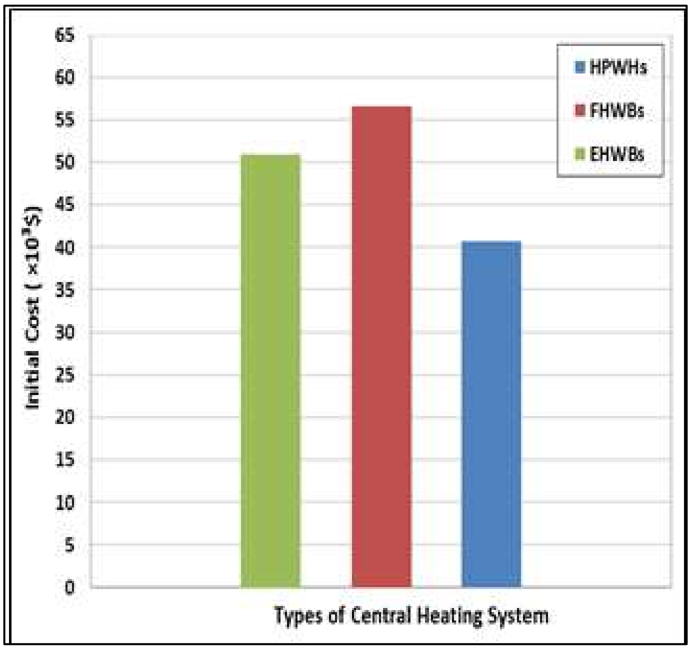

Figure 8: Initial Cost for Three Types of Central Heating Systems

Table 5: Monthly Running Cost with Twenty Hours per Day

System	Energy Consumption	Energy Price ($)	Running Cost ($)
EHWBs	56 kW	0.041$ / kW.Hr.	1,378 $
HPWHs	23.6 kW	0.041$ / kW.Hr.	581 $
FHWB	6.6 L/H	0.5 $ / Liter	1,980

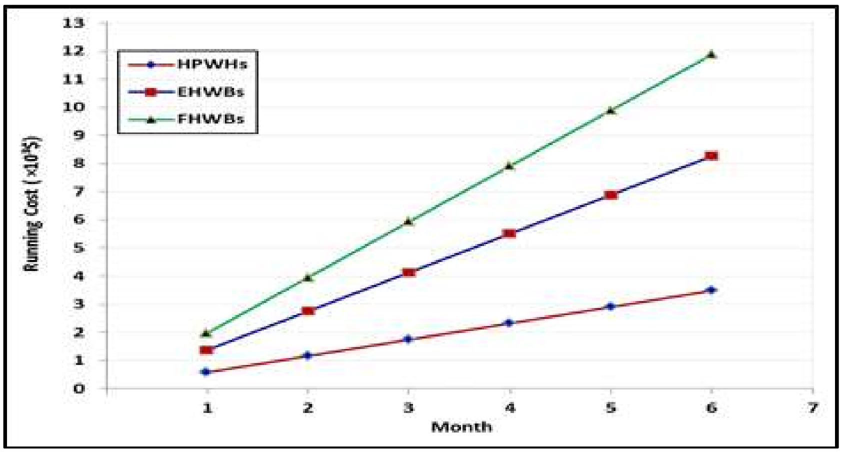

Figure 9: Running Cost for One Year for Different Types of Central Heating System

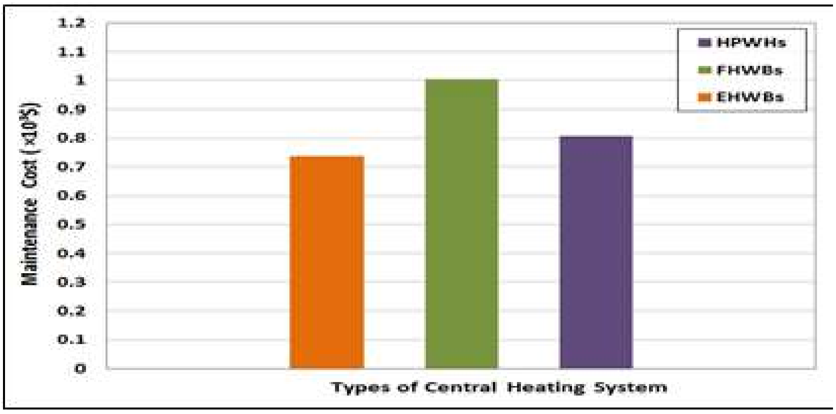

Figure 10: Yearly Maintenance Cost for Three Types of Central Heating System

Table 6: Maintenance Cost per One Year

System	EQP ($)	LIFE (Year)	Maintenance Cost ($)
FHWB	30,100	15	1,003
HPWH	24,200	15	806
EHWB	22,100	15	737

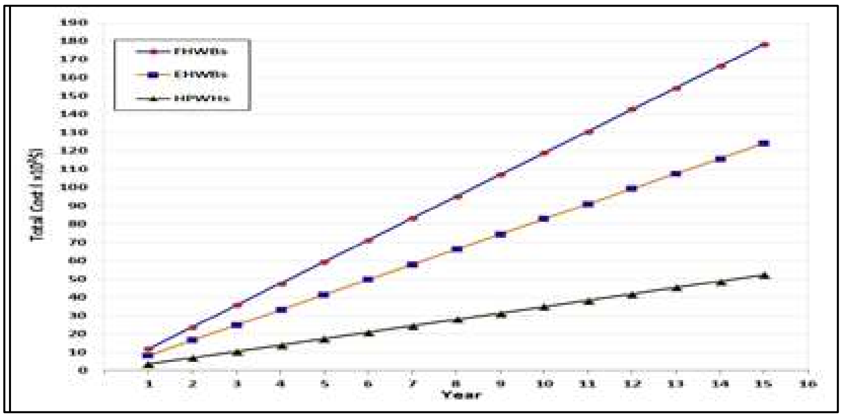

Figure 11: Life Cycle Cost for Fifteen Years of Central Heating System

References

[1] R. Saidur et al., "An application of energy and energy analysis in residential sector of Malaysia", Energy Policy 35, pp1050-1063, 2007.

[2] A. Aun, "Designing Low Energy Buildings Using Energy 10", (PAM), CPD Seminar 7th August, 2004.

[3] J. Kreider and A. Curtiss, "Heating and cooling of buildings", New York, McGraw Hill, 1994.

[4] B. Salim, "Life-Cycle Cost Analysis for three Different Types of A/C Systems Applied on an Apartment Located in a Multi-Floors Residential Tower in Mosul City", Engineering & Technology Journal ,Vol.32, Part (A), 2014.

[5] S. Wang, S. Pan and Y. Shi, "Analysis of Heating Systems and Scale of Natural Gas-Condensing Water Boilers in Northern Zones", ICEBO, Vol.3, PP.1-5, 2006.

[6] P. Cheng et al., "Economic Analysis of Composite Energy Heating System in the Cold Region", Elsevier, Procedia Engineering, Vol. 121, PP.1927 – 1931, 2015.

[7] V. Shah, D. Debella and R. Ries," Life cycle assessment of residential heating and cooling systems in four regions in the United States", Elsevier, Energy & Building , Vol. 40, PP. 503–513 , 2008.

[8] SMACNA, "HVAC Systems Duct Design", Chapter 2, 2006.

[9] ASHRAE, "ASHRAE Handbook HVAC Applications", Chapter 37, 2011.

[10] Wikipedia, "Dahuk Iraq Climate," My Forecast, Retrieved 2014. Website: https://en.wikipedia.org/wiki/Dohuk

[11] ASHRAE, "Handbook of Systems and Equipment", Chap.31, 2008.

[12] ASHRAE, "Handbook of Systems and Equipment", Chap.32, 2000.

[13] Taco Equipment Selection HVAC Solution Professional Software V7.6, 2014.

[14] B. Olesen, "Radiant Floor Heating In Theory and Practice", ASHRAE Journal, 2002.

[15] Avenir Software Tools Design, "Heat Cad", MJ8 Edition, 2015.

[16] Slant Fin Intrepid, "Oil Fired Water and Steam Boiler Book Data", 2016.

[17] Gree Corporation, "Heat Pump Water Heating Book Data", 2015.

[18] Electricity tariff and wages for ministry of electricity in Iraqi, November 2015.

[19] A. Elsafty and A. Al-Daini, "Economical comparison between a solar-powered vapor-absorption central heating system and a vapor-compression system in the Middle east", Renewable Energy 25, pp.569-583, 2002.

[20] G. Rosenquist et al., "Life-cycle Cost and Payback Period Analysis for Commercial Unitary Air Conditioners", Report, University of California, 2004.

[21] J. Tarquin and T. Blank, "Engineering Economy", McGraw Hill, 1976.

Authors Biography

Badran Mohammed Salim was born in Mosul, Iraq in 1981. He received his BSc in Mechanical Engineering in 2003, his MSc in heat transfer in semi-infinite grain storage filled with porous media in 2003. These degrees were all from the University of Mosul, Iraq. Now he is working in the Northern Technical University.

Ibrahim F. Abdulqadir was born in Mosul, Iraq in 1956. He received his BSc in Mechanical Engineering in 1979, he received his MSc in 2003. These degrees were all from the University of Mosul. Now he is working in the Duhok Polytechnic University.

Firas Mahmmod Younis was born in Mosul, Iraq in 1973. He received his BSc in Mechanical Engineering in 1994, he received his MSc in 1997. These degrees were all from the University of Mosul. Now he is working in the Duhok Polytechnic University.