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Energy Rating for Residential Buildings in Amman

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Abstract

The energy rating for residential buildings in Amman is studied and a rating scale is suggested. The annual cooling and heating energy requirement has been calculated according to Jordanian codes, using Hourly Analysis Program (HAP) and degree-days method (DD). The energy rating which provides the necessary information about the energy performance of the residential buildings has been assessed. The assessment is based on the thermal envelope. The annual energy loads are calculated for different cases according to different parameters such as glass layers for windows, and direction of the apartment. Two main cases are considered in constructing the energy rating scale; the cases are two apartments (one directed to the right while the other is directed to the left) located in Marka, Amman, Jordan. The two apartments have the same area of 110 m^2 and in the same building's floor. The different orientations have been considered for the apartments of 90, 180 and 270 degree clock wise rotations. Then, the heating and cooling loads are calculated for all orientations using single glass and double glass. The annual cooling and heating energy without rotation using degree-days method (DD): for case one are 123.8 kWh/m² (for single glass) and 112.8 kWh/m² (for double glass), and for case 2 are 125.9 kWh/m² (for single glass) and 114.6 kWh/m² (for double glass) at Tb=18.3 ℃ for heating and Tb =24 ℃ for cooling. These results are in good agreement with the HAP results. Finally, an energy rating scale was suggested for residential buildings in Amman.

Keywords: *Energy Rating, Degree-Days Method, Simulation*

1. Introduction

Energy Consumption is one of the most important issues in our life. Energy is used widely in many sectors, one of these sectors is the residential sector and the energy in this sector is used for different sources as shown in figure 1. Nowadays, the world is moving towards reducing the energy consumption as well as improving the energy efficiency of the building. This improvement will be very cost effective or maybe even free or at negative costs when implemented at study and this will be achieved by applying the energy rating requirements for the residential buildings.

The energy rating of residential buildings is a standard that measures the energy efficiency and evaluates the energy cost.

The energy rating is one of the potential strategies used to reduce energy consumption of the building based on the heating and cooling loads. The calculated loads rely on several factors, such as thermal insulation, window type and building characteristics; so that energy rating will be used to motivate consumers to use this information in purchase decision of their homes [1].

In many countries, different standards cover different regions and different types of buildings, such as residential or commercial buildings and more complicated high rise buildings. The design of the most residential buildings in Amman does not take into consideration the energy requirements such as best orientation and using the sun as an alternative source for free heating and natural lighting, it is very important to think efficiently about household energy; this can be achieved by implementing low energy buildings instead of traditional buildings.

The main purpose of this work is to study and analyze current approaches to encourage energy performance in residential building and to asset rating for this building in Amman. Including, estimating an energy rating scale and studying different cases for the building by changing its properties that

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affect directly on the performance. This study illustrates how energy efficiency can be improved, the best practice building with extremely low energy consumption and other strategies to increase buildings energy performance beyond minimum requirements.

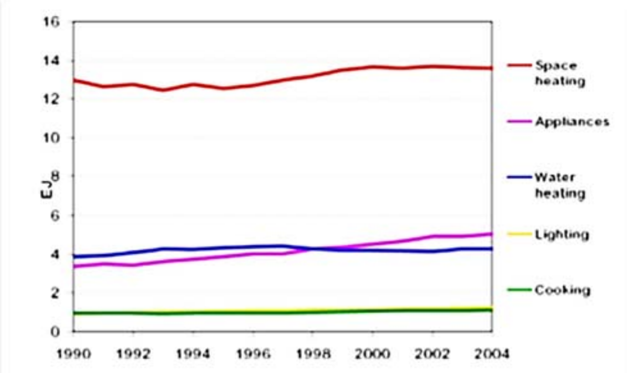

Figure 1: Energy use in residential buildings

The Jordanian Ministry of Public Work and Housing published many codes like Jordanian thermal insulation code, building efficient code and Jordan green building guide, these codes is used to be as a guide to reduce the energy consumption under the Jordanian climate conditions. The Jordanian building codes were prepared by utilizing regional, local and international related resources and the study recommendations for enhancing the energy performance is addressed in these building codes for new buildings [2].

A combination between architectural, mechanical and electrical considerations was added up into these codes in the region. The importance of energy efficiency requirements in building codes extends beyond their importance in buildings. These codes often serve as the efficiency target for improvements of residential buildings, buyers and renters of residential buildings will increase the demand for more improvements of existing buildings [3].

In this study different methods were used for rating the energy in residential buildings; these methods are applied to different cases for a typical apartment in Amman under different conditions and at each case the cooling and heating loads will be calculated to rate the energy performance according to these loads using the hourly analysis program (HAP), then the energy rating scale will be assumed. Based on this analysis different strategies will be suggested to achieve low energy buildings in Amman.

Since the energy simulation is a good method to predict the energy use of a building using software, so it will be done using HAP program for different cases of the building, then it can be used to model both energy consumption for heating, cooling, ventilation, lighting, and plug and process loads and water use in buildings.

2. Background

Traditional or historic buildings differ from modern buildings in energy consumption and energy conservation. Historic buildings deal with climatic conditions differently to modern structures and ill-considered alterations to improve energy efficiency.

Low energy building [4] - [9] is a modern building that consumes less energy from a traditional building by controlling its design and construction techniques. Low energy buildings are divided into three types: zero energy buildings [10], passive houses [10] and green building [11], many countries seek to achieve this type of buildings; basically to save energy.

As the energy rating is one of the most important scientific issues in the energy domain and especially for residential building; many literature studies have been done for many countries as shown below:

In some countries the term relates to a specific building standard. In particular, they seek to limit the energy used for space heating, since in many climate zones it represents the largest energy use. Other energy use may also be regulated. The history of passive solar building design gives an international look at one form of low-energy building development and standards.

In Germany a low-energy house *(Niedrigenergiehaus)* has maximum of 7 liters of heating oil for each square meter, for *space heating* annually (50 kWh/m²/yr.) [12]. On the other hand, the German *Passive house* ultra-low-energy standard, which has been applied in many European countries later, has a maximum space heating requirement of 15 kWh/m²yr [12]. A "sub-10 passive house" is under construction in Ireland that has an independently evaluated PHPP (Passive House) rating of 9.5 kW/m^2/year. Its form of construction also tackles the issue of embodied energy, which can significantly distort the lifecycle CO2 emissions associated with even low energy use houses [12].

In the United States, the ENERGY STAR program is the largest program defining low-energy homes and products. One of the major effects to energy star program is that it saves 15% of the total energy not like other systems, although homes nearly achieve 20%–30% savings. [12] The US Department of Energy formed a program in 2008 with the aim of spreading zero-energy housing over the US. Nowadays, participating builders commit to build new homes that save 30% on a home energy rating scale [12]. Home energy rating system (HERS)in which California energy commission published updated booklet which explain what is home energy rating and showed that the home is rated on a scale from 0 to 250 to show its efficiency relative to reference home, and provided whole house rating information [13]. The National Renewable Energy Laboratory, (2003), represented Morrison Homes at Lakeside community in Elk Grove, California. They plan on at least 10% of the homes being near-zero energy heating when the community is complete. Morrison is a part of the ENERGYSTAR program, which requires efficiency standards beyond California's strict Title 24 requirements [13]. In Las Vegas, the National Renewable Energy Laboratory, (2003), presented the ultimate family home created by Pardee Homes Show in Las Vegas, this attractive 5300 ft^2 home provides all the amenities needed by today families, with the added bonus of being a Zero Energy Home. Designed to be highly energy efficient and powered by 8 kilowatts of solar electricity and 1.5 kW of solar thermal energy, the home is expected to use 90% -100% less energy than a home built to code. The home also features solar collectors that provide hot water for the home [13]. Moreover, the National Renewable Energy Laboratory, (2003), mentioned that in August 2003, Clarun Homes opened the doors at Vista Montana, California's largest Zero Energy Home community, with homes designed to use almost zero net electricity over the course of a year. Built on a former apple orchard, all homes in development will harvest the sun to generate electricity. All homes will have solar electric systems that will provide at least 50% of annual energy [13].

Ali H, Al Nsairat S, (2009), contributed a better understanding of the concept of green building assessment tool and its role for achieving sustainable development through developing an effective green building rating system for residential units in Jordan in terms of the dimensions through which sustainable development tools are being produced and according to the local context [13]. Abo Daiyh A (2013), designed a green building in south of Jordan, he introduced building features such as wall and roof constructions, windows and PV system, also he used geothermal energy to cover some of building demands, importance of usage of thermal insulation in the building envelopes are introduced [13].

3. Heating and Cooling Load

3.1. Heating Load Calculations

The heating load of residential building consists of the heat loss rate through all exposed components such as walls, ceiling, floor, windows and all partition components, in addition to infiltration heating load required to warm outside cold air infiltrated to the heated space.

Heating load due to building structures

Calculation of heat transfer rate of heat losses through walls, ceiling, floor, doors and windows are estimated by using the following relation:

$$q = UA(T_i - T_o) \tag{1}$$

Where q is the rate of heat transfer (W), A is the heat transfer area (m^2), T_i is the inside air design temperature (℃), for winter it ranges between (19-21) ℃ for residential buildings from Jordanian thermal insulation codes, in the study it is taken as 21℃.
T_o is the outside air design temperature (℃); from Jordanian thermal insulation code the outside design temperature is classified into three zones according to the climate for each region: 5 for zone 1, 0 for zone 2 and -2 for zone 3. Through the study it is taken as 0℃ for Amman which located in zone 2.
U is the overall coefficient of heat transfer ($W/m^2.K$), which will be calculated from this equation:

$$U = 1/(R_i + \sum_{j=1}^{n}(R_{cond.})_j + R_o) \tag{2}$$

Where R_i and R_o are the inside and outside convection resistance of the air films, respectively.

$$\sum_{j=1}^{n}(R_{cond.})_j = R_1 + R_2 + \cdots R_n \tag{3}$$

Where n is the total number of homogeneous layers.
$R_{cond.}$ is the conduction thermal resistance, calculated from following relation:

$$R = d/k \ (m^2.K/W) \tag{4}$$

Where d is the layer thickness (m), k is the thermal conductivity for each layer ($W/m.K$)

For partitions that separate heated and unheated space is:

$$q = UA(T_i - T_{un}) \tag{5}$$

On the other hand, the equation used for the calculation of heat transfer rate through walls and floors below ground is:

$$q = UA(T_i - T_g) \tag{6}$$

Heating Load Due to Infiltration

The total heating load due to infiltration $\dot{q}_t$, is given by the equation:

$$\dot{q}_{t,f} = \dot{m}_f(h_i - h_o) \tag{7}$$

$\dot{m}_f$ is the mass flow rate for infiltrated outside air (kg/s) and it is calculated as below:

$$\dot{m}_f = \rho_o \dot{V}_v \tag{8}$$

ρ_o is the infiltrated air density at the outside temperature (kg/m^3) and its value can be calculated from:

$$\rho_o = (1/v_o) \tag{9}$$

Where v_o is the specific volume for the outside air at given outside temperature and is obtained from the Carrier psychometric chart.
The volumetric flow rate of infiltrated air $\dot{V}_f$ (m^3/h) is calculated by:

$$\dot{V}_f = N \times V_{room} \tag{10}$$

Where N is the number of air charge per hour obtained from tables and V_{room} is the room air volume (m^3).

h_i and h_o are the inside and outside specific enthalpies of infiltrated air; respectively. These values are obtained from Carrier psychometric chart.

Safety Factor

Safety factor is used to cover any extra load.

3.2. Cooling Load Calculations

Cooling load for the residential buildings consists of the following components:

Heat Gain Due to Sunlit Roofs and Walls

The calculation of this type of absorbed heat gain rate can be obtained by using the following relation for roofs and sunlit walls:

$$q = UA(CLTD) \tag{11}$$

Cooling load temperature difference (CLTD) is the total equivalent temperature difference which takes into consideration the increase of roof or wall temperature due to absorption of solar radiation. Cooling load is calculated as follows:

Heat Gain Due to Flat Sunlit Roofs

The equation below is used to calculate cooling load due to heat gain through flat sunlit roofs:

$$q = UA(CLTD)_{corr} \tag{12}$$

Where A is the surface area (m^2), U is the overall heat transfer coefficient ($W/m^2.K$) $and\ CLTD_{corr}$ is the corrected cooling load temperature difference which calculated from the following equation:

$$CLTD_{corr} = (CLTD + LM)k + (25.5 - T_i) + (T_{o,m} - 29.4)f \quad (13)$$

CLTD is the cooling load temperature difference (℃) that obtained from tables, LM is the latitude-month factor that obtained from tables, k is the color adjustment factor; for light colored roofs k=0.5 and for dark colored roofs k=1 [15], T_i is the inside design temperature (°C) and from the Jordanian thermal insulation code (2009) for residential buildings it ranges between (21-23) ℃ through the calculations it is taken as 23℃ and $T_{o,m}$ is the outside mean temperature (℃); it is obtained from the following relation:

$$T_{o,m} = 0.5(T_{max} + T_{min}) \quad (14)$$

Where T_{max} is the average maximum monthly mean daily temperature for month of the summer season (℃), that obtained from tables. T_{min} is the average minimum monthly mean daily temperature for month of the summer season (℃), that obtained from tables. The factor f is taken as 1 if there is no attic or roof fan (such as most buildings in Jordan) and is taken as 0.75 if there is an attic or roof fan [15].

Heat Gain Due to Vertical Sunlit Walls

The equation below is used to calculate the heat gain due to vertical sunlit walls:

$$q = UA(CLTD)_{corr} \quad (15)$$

$(CLTD)_{corr}$ is obtained from equation 13.

Heat Transfer Rate Due to Partitions

The equation below is used to calculate the heat transfer rate through partitions:

$$q_{adj} = UA(T_{adj} - T_i) \quad (16)$$

T_{adj} is the unconditioned space temperature (℃).

Heat Gain Due to Sunlit Glass Surfaces

The total heat gain rate due to an exposed glass area is the sum of transmission heat gain rate and the heat gain rate due to heat convection as follows:

Heat Gain Due to Solar Transmission through Glass

Heat Gain due to solar transmission through glass is calculated using the equation below:

$$q_{tr} = A(SHG)(SC)(CLF) \quad (17)$$

Where SHG is the solar heat gain rate (W/m^2) that extracted from tables and SC is the shading coefficient factor that obtained from tables. The CLF is termed as the cooling load factor, which represents the effect of the internal walls, floor and furniture on the instantaneous cooling load. This factor is obtained from tables.

Convection Heat Gain through Glass

The convection heat gain rate component due to glass surfacesq_{conv}, is calculated from the following equation:

$$\dot{q}_{conv.} = UA(CLTD)_{corr} \quad (18)$$

$(CLTD)_{corr}$ is obtained from equation 13 while $CLTD$ is obtained from tables. The value of the color factor k is taken as equal to 1[15].

Cooling Load Due to Infiltration

Cooling load due to infiltration $q_{\ t,f}$(W) is calculated using air change method (ACH) as follows:

$$q_{\ t,f} = \dot{m}_f(h_o - h_i) \quad (19)$$

Cooling Load Due to Occupants

Cooling load due to occupants is calculating by using the equation below:

$$q_{occ} = n[\dot{q}_{sen}(CLF)_{occ} + \dot{q}_{lat}] \quad 20$$

Where n is the number of occupants inside the air conditioned space, $\dot{q}_{sen}$is the sensible heat (W/person), $\dot{q}_{lat}$ is the latent heat (W/person), and CLF_{occ} is the cooling load factor for occupants, $\dot{q}_{sen}$, $\dot{q}_{lat}$ and CLF_{occ} values are from tables.

Cooling Load Due to Lighting

Lighting affects directly on the cooling load calculation and its effect obtained from the following equation:

$$q_{\ Lt} = P_{Lt}(F_uF_b)(CLF)_{Lt} \quad (21)$$

Since;

P_{Lt} is the rated power of the lamps which obtained as follows:

$$P_{Lt} = (lamp\ intensity * A)(W) \quad (22)$$

Where F_u is the fraction of lamp,F_b is the ballast factor that equals to 1.0 for ordinary lamps and 1.2 for fluorescent lamps and CLF_{Lt} is the cooling load factor for lights that obtained from tables.

Cooling Load Due to Appliances

Appliances that used in residential buildings play an important role in cooling load calculations and its cooling load is calculated as following:

$$\dot{q}_{app} = n(\dot{q}_{sen}(CLF)_{App} + \dot{q}_{Lat}) \quad (23)$$

Where; n is the number of appliances, $\dot{q}_{sen}$ and $\dot{q}_{Lat}$ are the sensible and latent heat gain rate, respectively. Their values are obtained from tables.

CLF_{app} is the cooling load factor for appliances that obtained from tables.

Safety Factor

Safety factor is used to cover any extra load.

3.3. Building Characteristics

The building located in Amman (Markka) at 32˚ latitude, 36˚ longitude and 774 m elevation [14] which located in zone 2 according to the thermal insulation code. This case study is conducted on a typical apartment shown in figure 2 that is commonly spread of Jordanian residential buildings. The apartment's total area is 110 m^2 and it consists of three bedrooms, kitchen, two baths, saloon and living room. The occupancy is 6 persons. Natural ventilation criteria are used by opening doors and windows. U-value will be calculated for exposed walls, partition, roof and floor using Jordanian thermal insulation code.

Figure 2: Apartment Layout

External walls U-value

The layers of exposed walls are listed in table 1, figure 3 summarizes wall layers. The k and ρ values for each wall layer are obtained from tables, Table 1 below lists k and ρ values.

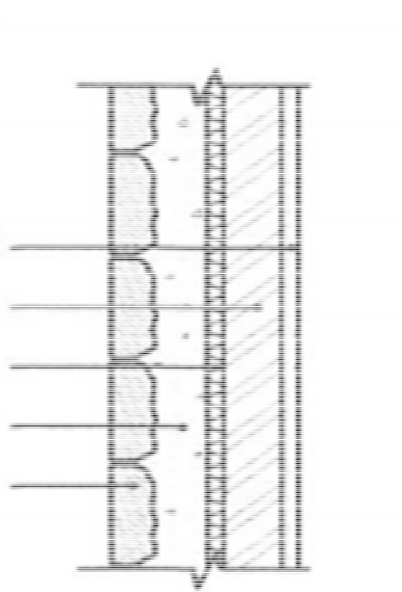

Figure 3: Exposed wall layers

Table 1: Density and thermal conductivity values for exposed walls layers

Layer	Density (Kg/m^3)	k value (W/m.K)	Thickness (cm)
Stone	1650	0.9	7
Concrete	1000	0.3	23
Insulation	30	0.036	3
Concrete block	1000	0.65	7
Plaster	1570	0.53	2

The overall heat transfer coefficient for exposed walls is calculated as follows:

From equation 3

$\sum R_j = 1.823\ m^2.K/W$

$R_{th} = R_O + \sum R_j + R_i = 1.993\ m^2.K/W$

With $R_o = 0.04\ m^2.K/W$, $R_i = 0.13\ m^2.K/W$ from tables.

$U_{th} = \frac{1}{R_{th}} = 0.502\ W/m^2.K \leq 0.57\ m^2.K/W$ (meets code requirement).

Partitions U-value

The layers of the partitions are shown in figure 4, table 2 below lists the k and ρ values for each layer.

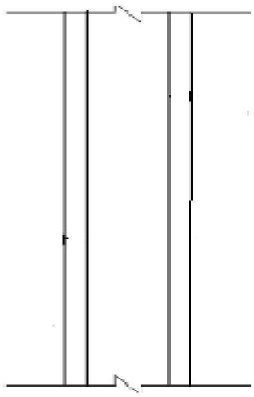

Figure 4: Partition layers

Table 2: Density and thermal conductivity values for partitions

Layer	Density (Kg/m^3)	k value (W/m.K)	Thickness (cm)
Plaster	1570	0.53	3
Block	1000	0.65	10
Plaster	1570	0.53	3

The overall heat transfer coefficient for partitions is calculated as follows:

$R_i = R_o = 0.13\ m^2.k/W$ from tables.

$R_{th} = R_i + \sum_{j=1}^{n}(R_{cond.})_j + R_o$, where $R_{th} = 0.527\ m^2.K/W$

$U_{th} = \frac{1}{R_{th}} = 1.897\, W/m^2.K\ \leq 2m^2.K/W$ (meets code requirement).

Roof U-value

The roof construction is shown in figure 5, table 3 below lists the k and ρ values for each roof layer to calculate U –value.

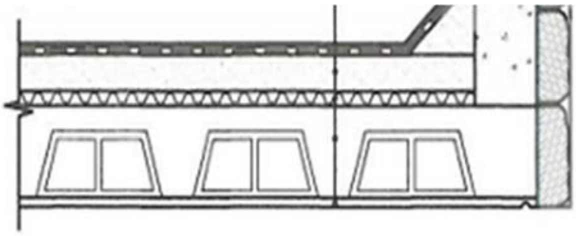

Figure 5: Roof Layers

Table 3: Density and thermal conductivity values for roof

Layer	Density (Kg/$\boldsymbol{m^3}$)	k value (W/m.K)	Thickness (cm)
Water proof	2300	0.7	2
Light weight concrete	1400	0.56	12
Thermal insulation	40-65	0.039	4
Concrete	1400	0.56	8
Cement ribs	1000	0.65	18
Plaster	1570	0.53	3

The overall heat transfer coefficient for roof is calculated as follows:
From equation 3:$R_1 = 1.789m^2.K/W$ and $R_2 = 1.745m^2.K/W$. Since; $R_i = 0.1m^2.K/W, R_o = 0.04\, m^2.K/W$ from tables, using equation 2:$U_1 = 0.518\, W/m^2.K\, , U_2 = 0.531\ W/m^2.K$
$U_R = \frac{1}{5}U_1 + \frac{4}{5}U_2 = 0.528\ W/m^2.k \leq\ 0.55\ W/m^2.K$
(meets code requirement).

Floor/ceiling U-value

Figure 6 below shows the floor layers and table 4 lists the k and ρ values for each floor layer which obtained from tables to calculate floor U –value.

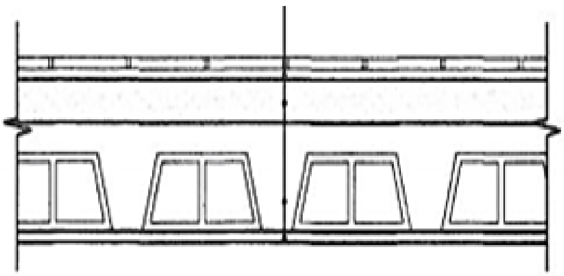

Figure 6: Floor/Ceiling Layers

Table 4: Density and thermal conductivity values for floor /ceiling layers

Layer	Density (Kg/$\boldsymbol{m^3}$)	k value (W/m.K)	Thickness (cm)
Cement tiles	2100	1.1	2.5
Mortar	1880	0.54	2.5
Sand	1500	0.3	6
Concrete	1400	0.56	8
Cement ribs	1000	0.65	18
Plaster	1570	0.53	3

The overall heat transfer coefficient for floor is calculated as follows:

From equation 3:

$R_1 = 0.7899m^2.K/W$ and $R_2 = 0.745m^2.K/W$

Since; $R_i = 0.17\ \ W/m^2.K\, , R_o = 0.04\, W/m^2.K$ from tables and by using equation 2:

$U_1 = 1\, W/m^2.K\, , U_2 = 1.047\, W/m^2.K$

$U_f = \frac{1}{5}U_1 + \frac{4}{5}U_2 = 1.038 \leq 1.2\, W/m^2.K$ (meets code requirement).

Windows U-value

Single glazing window with metal aluminum frame with U-value equal to 5.7 (W/m². K) is used. Exposed wall with opening windows should not exceed 1.6 (W/m². K). The U-value for exposed walls (North, West and East) with openings were calculated using the equation $U_w * A_w + U_g * A_g$
and found to meet code requirement for all walls as listed in Table 5.

Table 5: The overall heat transfer coefficient values for entire apartment

Building structure	U-value (W/m².K)	Maximum U-value (W/m².K)
exposed walls	0.502	0. 57
floor/ceiling	1.038	1.2
partition	1.897	2
windows	5.7	-
roof	0.528	0.55
Exposed wall with opening		
North wall	1.307	1.6
East wall	1.53	1.6
West wall	1.59	1.6

4. Building Energy Rating

Here the energy rating for building in Markka, Amman will be assessed, based on the annual heating and cooling energy demands using HAP simulation.

4.1. Case Study

Two cases are studied to estimate the energy rating scale:

Case one: This case study includes the typical right section apartment that's found in real life in Jordan in figure 7, apartment area equals =110 m^2, the U-value for floor, roof and exposed walls are calculated according to the Jordanian thermal insulation code that mentioned in chapter three. Since the orientation of the apartment plays important role in cooling load, the apartment is rotated 90,180,270 degrees clock wise and results in cases A, B, C and D, respectively as shown in figure 8. It is worth mentioning that the floor above and below the apartment are assumed unconditioned floors.

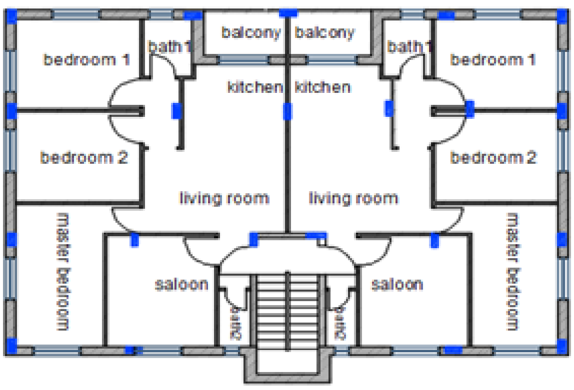

Figure 7: Cases one and two layout

Figure 8: Case one layout with several orientations

Then the heating and cooling loads are calculated for all orientations, for single glass and double glass with U-value equals to 5.7, 3.3 W/m^2.K, respectively (using HAP program).

Case two: This case study includes the typical left section apartment in figure 7; it's similar to case one. The left apartment is rotated 90,180,270 degrees counter clock wise. Then the heating and cooling loads are calculated for all orientations, for single glass and double glass with U-value equals to 5.7, 3.3 W/m^2.K, respectively (using HAP program).Table 6 shows the results of the different cases.

Table 6: Heating and cooling loads for the different cases in kilowatt

		Cooling Load		Heating Load	
		Single glass	Double glass	Single glass	Double glass
Case one	A	11.9	11.3	8.3	7.4
	B	11.1	10.7	8.3	7.4
	C	11.9	11.5	8.3	7.4
	D	11.8	11.3	8.3	7.4
Case two	A	12.5	11.8	8.3	7.4
	B	11.3	10.8	8.3	7.4
	C	11.6	11.2	8.3	7.4
	D	11.2	10.7	8.3	7.4

4.2. The Degree-Days Method (DD)

The Degree-Day method [16] based on the assumption that the heating or cooling load is proportional to the difference between the mean daily outdoor temperature T_m and the outdoor temperature called base temperature T_b. The mean temperature is an average of maximum and minimum outdoor temperature during the day, the base temperature is the outdoor temperature below or above which heating or cooling required for the space, respectively. To estimate energy rating scale, annual energy requirements of a conventional cooling and heating systems per meter square are needed as shown in tables 7 and 8.

Table 7: The Annual energy requirements for cooling and heating

	Annual heating and cooling energy requirements (KWH)	Annual heating and cooling energy requirements per area (KWH/m²)	Annual heating and cooling energy requirements (KWH)	Annual heating and cooling energy requirements per area (KWH/m²)
	Single glass		Double glass	
Case one				
A	8,131	87.4	7,792	83.8
B	7,776	83.6	7,563	81.3
C	8,082	86.9	7,989	85.9
D	7,921	85.2	7,697	82.8
Case two				
A	8,284	89.1	8,048	86.5
B	7,538	81.1	7,343	79.0
C	8,167	87.8	7,831	84.2
D	7,859	84.5	7,533	81.0
Case three				
A	7,939	85.4	7,690	82.7
B	7,623	82.0	7,468	80.3
C	7,970	85.7	7,882	84.8
D	7,769	83.5	7,586	81.6
Case four				
A	9,319	100.2	8,107	87.2
B	9,010	96.9	7,877	84.7
C	9,336	100.4	8,306	89.3
D	9,119	98.1	8,039	86.4

Table 8: The Annual energy requirements for cooling and heating

	Annual heating and cooling energy requirements per area (kWh/m²) using T_b =15.5°C T_b =24°C		Annual heating and cooling energy requirements per area (kWh/m²) using T_b =18.3°C, T_b =24°C	
Case one	Single glass	Double glass	Single glass	Double glass
A	92.6	86.9	123.8	112.8
B	90.4	84.8	120.9	110.7
C	93.3	87.6	123.8	113.5
D	92.6	86.9	123.4	112.8
Case two				
A	94.4	88.7	125.9	114.6
B	90.8	85.1	121.6	111.0
C	92.2	86.5	122.7	112.4
D	90.4	84.8	121.3	110.7

4.3. Simulation Energy Using HAP Program.

Carrier's hourly analysis program is designed for consultancy services by calculating heating and cooling loads and an energy simulation can be done annually, detailed simulation of air system operation to determine cooling coil loads and heating coil loads and other aspects of system performance 24-hours a day for design days in each of the 12 months, it uses TMY weather data and the Transfer Function Method. Different types of systems can be simulated. Results are shown in table 9.

Table 9: Energy simulation for different cases

	Annual heating and cooling energy requirements per area (kWh/m²) using T_b=18.3℃, T_b =22℃		Annual heating and cooling energy requirements per area (kWh/m²) using T_b=15.5℃, Tb =22°c	
Case one	Single glass	Double glass	Single glass	Double glass
A	169.7	156.5	140.7	130.6
B	163.8	152.0	134.8	126.1
C	169.7	157.9	140.7	132.1
D	169.0	156.5	140.0	130.6
Case two				
A	174.2	160.2	145.2	134.3
B	165.3	152.8	136.3	126.9
C	167.5	155.7	138.5	129.8
D	164.6	152.0	135.5	126.1

4.4. Suggested Energy Rating Scale

According to the annual energy that calculated for several cases in Amman, energy rating scale is suggested based on T_b=18.3℃ for heating and T_b=24℃ for cooling as shown in figure 9. For example, Buildings with annual energy requirement of heating and cooling systems ≤ 25 kWh/m² are rated with A1.

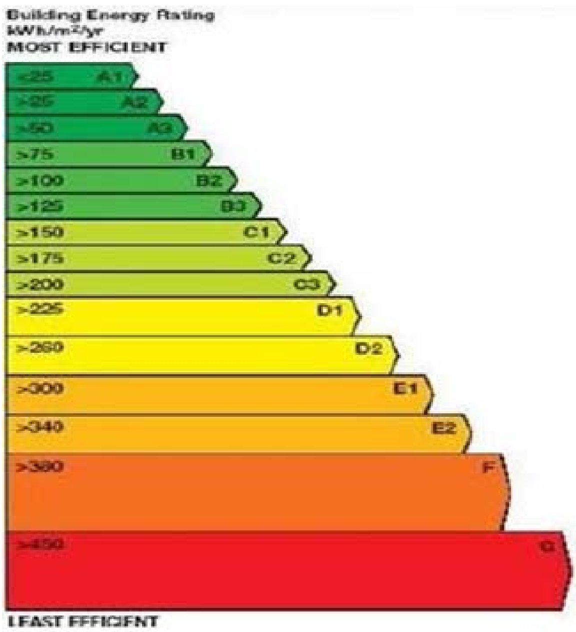

Figure 9: Suggested energy rating scale

Table 10 below summarizes the building energy rating scale.

Table 10: Suggested energy rating scale

Rate	Total energy per area (kWh/m²)	Rate	Total energy per area (kWh/m²)
A1	≤ 25	C2	≥175
A2	≥ 25	C3	≥200
A3	≥ 50	D1	≥250
B1	≥ 75	D2	≥ 300
B2	≥100	E1	≥ 340
B3	≥ 125	E2	≥ 380
C1	≥150	F	≥ 450
		G	≥ 450

5. Conclusion

Through this study, the annual heating and cooling loads for residential buildings using the HAP program were calculated. Then, the energy for the building was estimated. The Jordanian codes (thermal insulation code (2009), energy efficient building code and green building guide) were used. And the U-values for walls, roof and floor were considered to minimize the energy losses as much as possible. Finally a building energy rating scale was suggested.

The annual heating and cooling energy requirements were calculated for the most current Jordanian buildings which are in compliance with Jordanian thermal insulation code (2009) using HAP program and degree-days method on the basis of T_b= 18.3℃ for heating and T_b= 24℃ for cooling. The values are in the range between (110-120) kWh/m^2, which rated with B2 according to the suggested building energy rating scale.

The calculated annual heating and cooling energy requirements for the Jordanian residential buildings which are in compliance with Jordanian thermal insulation code (2009) using HAP program and degree-days method on the basis of T_b= 15.5℃ for heating and T_b= 24℃ for cooling. The values are in the range between (80-90) kWh/m^2, which rated with B1 according to the suggested building energy rating scale.

The calculated annual heating and cooling energy requirements for the Jordanian residential buildings which are compliance with Jordanian thermal insulation code (2009) using HAP program and degree-days method on the basis of T_b= 15.5℃ for heating and T_b= 22℃ for cooling. The values are in the range between (120-140) kWh/m^2, which rated with B3 according to the suggested building energy rating scale.

The calculated annual heating and cooling energy requirements for the Jordanian residential buildings which are in compliance with Jordanian thermal insulation code (2009) using HAP program and degree-days method on the basis of T_b= 18.3℃ for heating and T_b= 22℃ for cooling. The values are in the in range between (145-165) kWh/m^2, which rated with C1 according to the suggested building energy rating scale.

From the current study of energy rating for residential buildings in Amman, we reach to these results: Annual heating and cooling loads for residential building depend directly on different factors such as: direction of the building, building properties, window type and insulation thickness.

There are many techniques to help increasing the performance of the building, these techniques are: Using double glass window instead of single glass, increasing the insulation thickness in the exposed walls, choosing the appropriate orientation of the building in which the benefits of sun rays can be used, using the renewable energy resources instead of fuel sources and using shadow of the windows and trees shadow to reduce the loads as much as we can.

Nowadays the whole world moves toward reducing the energy consumption of the residential buildings by designing the low energy buildings that decrease the CO_2 emissions to the environment. These environmental friendly and the low energy buildings decrease the fuel consumption. It is worth mentioning that the additional cost of the low energy buildings will lead to annual energy savings that pays back in acceptable period.

Nomenclature

A	Surface Area.
ACH	Air Change Method.
CLF	Cooling Load Factor.
CLF_{occ}	The Cooling Load Factor for Occupants.
CLF_{Lt}	The Cooling Load Factor for Light.
CLTD	The Cooling Load Temperature Difference.
$\mathbf{CLTD_{corr}}$	The Corrected Cooling Load Temperature Difference.
d	Thickness.
DB	Dry bulb temperature.
DD	Degree-Days Method.
DD_c	Cooling Degree-Days.
DD_H	Heating Degree-Days.
F_b	Ballast Factor.
F_u	Fraction of Lamp That Are in Use.
HAP	Hourly Program Analysis.
h_i	Inside Specific Enthalpy.
h_o	outside Specific Enthalpy
HVAC	Heating and Ventilation Air Conditioning.
K	Thermal Conductivity of Material.
k	The Color Adjustment Factor.
LM	Latitude-Month Correction Factor.
n	Number of occupants inside the air conditioned space.
P_{Lt}	The Rated Power of the Lamps.
P_{lt}	Rated power of the lamps.
q'_{sen}	Heat Gain Rate.
q_{adj}	Heat Rate Transferred through partition.
q_c	Calculated Cooling load.

$Q_{c,theor}$ Design Energy Requirement for Conventional Cooling System.

q_{conv} Convection Heat Gain Rate Component Due to Glass Surface.

q_f Heating Load Due to Infiltration.

q_{gain} Heat Gain

q_h Calculated Heating load.

$Q_{H,theor}$ Design Energy Requirement for Conventional Heating System.

q_{loss} Heat loss.

$q_{s,occ}$ Sensible Heat Gain Rate Due to Occupant.

q_{tr} Heat Gain Due to Solar Transmission

R Thermal Resistance

R_i Interior Surface Thermal Resistance.

$R_{cond.}$ The Conduction Thermal Resistance.

R_o Exterior Surface Thermal Resistance.

SC Shading Coefficient Factor.

SHG Solar Heat Gain Rate Factor.

T_{adj} Unconditioned Space Temperature.

T_g Ground Temperature.

T_i Inside Design Temperature.

T_{max} The Average Maximum Monthly Mean Daily Temperature for Month.

T_{min} The Average Minimum Monthly Mean Daily Temperature for Month.

T_o Outside Design Temperature.

$T_{o,m}$ Outside Mean Temperature.

T_{un} Unconditioned Space Temperature.

U Over Heat Transfer Coefficient.

V_{room} Volume of the Room.

v_o The Specific Volume.

WB Wet bulb temperature.

ρ_o The Air Density.

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