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 m² and in the same building’s floor. The different orientations have been considered for the apartments of 90, 180 and 270 degree clockwise 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 °C for heating and Tb =24 °C 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
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/m² yr [12]. A “sub-10 passive house” is under construction in Ireland that has an independently evaluated PHPP (Passive House) rating of 9.5 kW/m²/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 ENERGY STAR 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 ft² 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
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:

\[ q = UA(T_i - T_0) \]  
(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 (°C), for winter it ranges between (19-21) °C for residential buildings from Jordanian thermal insulation codes, in the study it is taken as 21°C. 

\( T_0 \) is the outside air design temperature (°C); 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°C 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:

\[ U = 1/(R_i + \sum_{j=1}^{n}(R_{cond,j}) + R_o) \]  
(2)

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

\[ \sum_{j=1}^{n}(R_{cond,j}) = R_1 + R_2 + \cdots + R_n \]  
(3)

Where \( n \) is the total number of homogeneous layers. 

\( R_{cond} \) is the conduction thermal resistance, calculated from following relation:

\[ R= d/k \text{ (m}^2\text{K/W) } \]  
(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:

\[ q = UA(T_i - T_{un}) \]  
(5)

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

\[ q = UA(T_i - T_g) \]  
(6)

**Heating Load Due to Infiltration**

The total heating load due to infiltration \( q_{inf} \), is given by the equation:

\[ q_{inf} = \dot{m}_f(h_i - h_o) \]  
(7)

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

\[ \dot{m}_f = \rho_o \dot{V}_f \]  
(8)

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

\[ \rho_o = (1/v_o) \]  
(9)

Where \( v_o \) is the specific volume for the outside air at given outside temperature and is obtained from the Carrier psychrometric chart.

The volumetric flow rate of infiltrated air \( \dot{V}_f \) (m\(^3\)/h) is calculated by:

\[ \dot{V}_f = N \times V_{room} \]  
(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 psychrometric 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:

\[ q = UA(\text{CLTD}) \]  
(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:

\[ q = UA(\text{CLTD})_{corr} \]  
(12)
Where A is the surface area ($m^2$), U is the overall heat transfer coefficient ($W/m^2K$) and \( CLTD_{corr} \) is the corrected cooling load temperature difference which calculated from the following equation:

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

\( CLTD \) is the cooling load temperature difference (°C) 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) °C through the calculations it is taken as 23°C and \( T_{o,m} \) is the outside mean temperature (°C); it is obtained from the following relation:

\[
T_{o,m} = 0.5(T_{max} + T_{min})
\]  
(14)

Where \( T_{max} \) is the average maximum monthly mean daily temperature for month of the summer season (°C), that obtained from tables, \( T_{min} \) is the average minimum monthly mean daily temperature for month of the summer season (°C), 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:

\[
q = UA(CLTD)_{corr}
\]  
(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:

\[
q_{adj} = UA(T_{adj} - T_i)
\]  
(16)

\( T_{adj} \) is the unconditioned space temperature (°C).

**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:

\[
q_{trans} = A(SHG)(SC)(CLF)
\]  
(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 surfaces \( q_{conv} \), is calculated from the following equation:

\[
q_{conv} = UA(CLTD)_{corr}
\]  
(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 \( q_{if} (W) \) is calculated using air change method (ACH) as follows:

\[
q_{if} = n_2(b_2 - h_3)
\]  
(19)

**Cooling Load Due to Occupants**

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

\[
q_{occ} = n_2[q_{sens}(CLF)_{occ} + q_{lat}]
\]  
(20)

Where \( n_2 \) is the number of occupants inside the air conditioned space, \( q_{sens} \) is the sensible heat (W/person), \( q_{lat} \) is the latent heat (W/person), and \( CLF_{occ} \) is the cooling load factor for occupants, \( q_{sens}, q_{lat} \) 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:

\[
q_{lt} = P_{lt}(F_1F_2)(CLF)_{lt}
\]  
(21)

Since;

\[
P_{lt} = (\text{lamp intensity} \times A)(W)
\]  
(22)

Where \( F_1 \) is the fraction of lamp, \( F_2 \) 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:

\[
q_{app} = n_2(q_{sens}(CLF)_{app} + q_{lat})
\]  
(23)

Where; \( n_2 \) is the number of appliances, \( q_{sens} \) and \( q_{lat} \) 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 m² 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.

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

<table>
<thead>
<tr>
<th>Layer</th>
<th>Density (Kg/m²)</th>
<th>k value (W/m.K)</th>
<th>Thickness (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone</td>
<td>1650</td>
<td>0.9</td>
<td>7</td>
</tr>
<tr>
<td>Concrete</td>
<td>1000</td>
<td>0.3</td>
<td>23</td>
</tr>
<tr>
<td>Insulation</td>
<td>30</td>
<td>0.036</td>
<td>3</td>
</tr>
<tr>
<td>Concrete block</td>
<td>1000</td>
<td>0.65</td>
<td>7</td>
</tr>
<tr>
<td>Plaster</td>
<td>1570</td>
<td>0.53</td>
<td>2</td>
</tr>
</tbody>
</table>

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

From equation 3

\[ R_{th} = R_o + \sum R_j + R_i = 1.993 \text{ m}^2 \cdot \text{K/W} \]

With \( R_o = 0.04 \text{ m}^2 \cdot \text{K/W} \), \( R_i = 0.13 \text{ m}^2 \cdot \text{K/W} \) from tables.

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

Partitions U-value

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

Table 2: Density and thermal conductivity values for partitions

<table>
<thead>
<tr>
<th>Layer</th>
<th>Density (Kg/m²)</th>
<th>k value (W/m.K)</th>
<th>Thickness (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaster</td>
<td>1570</td>
<td>0.53</td>
<td>3</td>
</tr>
<tr>
<td>Block</td>
<td>1000</td>
<td>0.65</td>
<td>10</td>
</tr>
<tr>
<td>Plaster</td>
<td>1570</td>
<td>0.53</td>
<td>3</td>
</tr>
</tbody>
</table>

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

\[ R_i = R_o = 0.13 \text{ m}^2 \cdot \text{K/W} \] from tables.

\[ R_{th} = R_i + \sum\limits_{j=1}^{n} (R_{cond})_j + R_o, \text{ where } R_{th} = 0.527 \text{ m}^2 \cdot \text{K/W} \]
The overall heat transfer coefficient for roof is calculated as follows:

From equation 3:

\[ R_1 = 0.7899 \text{m}^2 \cdot \text{K}/\text{W} \] and \[ R_2 = 0.745 \text{m}^2 \cdot \text{K}/\text{W} \]

Since; \[ R_1 = 0.17 \text{ m}^2 \cdot \text{K}/\text{W}, R_o = 0.04 \text{ m}^2 \cdot \text{K}/\text{W} \] from tables and by using equation 2:

\[ U_f = \frac{1}{5} U_1 + \frac{4}{5} U_2 = 1.038 \leq 1.2 \text{ m}^2 \cdot \text{K}/\text{W} \] (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 \[ U_w + A_w + U_o + A_o \] 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

<table>
<thead>
<tr>
<th>Building structure</th>
<th>U-value (W/m².K)</th>
<th>Maximum U-value (W/m².K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>exposed walls</td>
<td>0.502</td>
<td>0.57</td>
</tr>
<tr>
<td>floor/ceiling</td>
<td>1.038</td>
<td>1.2</td>
</tr>
<tr>
<td>partition</td>
<td>1.897</td>
<td>2</td>
</tr>
<tr>
<td>windows</td>
<td>5.7</td>
<td>-</td>
</tr>
<tr>
<td>roof</td>
<td>0.528</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Exposed wall with opening

<table>
<thead>
<tr>
<th></th>
<th>U-value (W/m².K)</th>
<th>Maximum U-value (W/m².K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North wall</td>
<td>1.307</td>
<td>1.6</td>
</tr>
<tr>
<td>East wall</td>
<td>1.53</td>
<td>1.6</td>
</tr>
<tr>
<td>West wall</td>
<td>1.59</td>
<td>1.6</td>
</tr>
</tbody>
</table>

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 m², 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.

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/m².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

<table>
<thead>
<tr>
<th></th>
<th>Cooling Load</th>
<th>Heating Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single glass</td>
<td>Double glass</td>
</tr>
<tr>
<td><strong>Case one</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>11.9</td>
<td>11.3</td>
</tr>
<tr>
<td>B</td>
<td>11.1</td>
<td>10.7</td>
</tr>
<tr>
<td>C</td>
<td>11.9</td>
<td>11.5</td>
</tr>
<tr>
<td>D</td>
<td>11.8</td>
<td>11.3</td>
</tr>
<tr>
<td><strong>Case two</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>12.5</td>
<td>11.8</td>
</tr>
<tr>
<td>B</td>
<td>11.3</td>
<td>10.8</td>
</tr>
<tr>
<td>C</td>
<td>11.6</td>
<td>11.2</td>
</tr>
<tr>
<td>D</td>
<td>11.2</td>
<td>10.7</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Case</th>
<th>Single glass</th>
<th>Double glass</th>
<th>Single glass</th>
<th>Double glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8.131</td>
<td>87.4</td>
<td>7.792</td>
<td>83.8</td>
</tr>
<tr>
<td>B</td>
<td>7.775</td>
<td>83.6</td>
<td>7.355</td>
<td>81.3</td>
</tr>
<tr>
<td>C</td>
<td>8.082</td>
<td>86.9</td>
<td>7.989</td>
<td>85.9</td>
</tr>
<tr>
<td>D</td>
<td>7.921</td>
<td>85.2</td>
<td>7.697</td>
<td>82.8</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Case</th>
<th>Single glass</th>
<th>Double glass</th>
<th>Single glass</th>
<th>Double glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>169.7</td>
<td>156.5</td>
<td>140.7</td>
<td>130.6</td>
</tr>
<tr>
<td>B</td>
<td>163.8</td>
<td>152.0</td>
<td>134.8</td>
<td>126.1</td>
</tr>
<tr>
<td>C</td>
<td>169.7</td>
<td>157.9</td>
<td>140.7</td>
<td>132.1</td>
</tr>
<tr>
<td>D</td>
<td>169.0</td>
<td>156.5</td>
<td>140.0</td>
<td>130.6</td>
</tr>
</tbody>
</table>

Table 8: The Annual energy requirements for cooling and heating

<table>
<thead>
<tr>
<th>Case</th>
<th>Single glass</th>
<th>Double glass</th>
<th>Single glass</th>
<th>Double glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>92.6</td>
<td>86.9</td>
<td>123.8</td>
<td>112.8</td>
</tr>
<tr>
<td>B</td>
<td>90.4</td>
<td>84.8</td>
<td>120.9</td>
<td>110.7</td>
</tr>
<tr>
<td>C</td>
<td>93.3</td>
<td>87.6</td>
<td>123.8</td>
<td>113.5</td>
</tr>
<tr>
<td>D</td>
<td>92.6</td>
<td>86.9</td>
<td>123.4</td>
<td>112.8</td>
</tr>
</tbody>
</table>

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 $T_b=18.3\,^\circ C$ for heating and $T_b=24\,^\circ C$ 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>
<thead>
<tr>
<th>Rate</th>
<th>Rate</th>
<th>Total energy per area (kWh/m²)</th>
<th>Total energy per area (kWh/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>≤  25</td>
<td>C2</td>
<td>≥175</td>
</tr>
<tr>
<td>A2</td>
<td>≥ 25</td>
<td>C3</td>
<td>≥200</td>
</tr>
<tr>
<td>A3</td>
<td>≥ 50</td>
<td>D1</td>
<td>≥250</td>
</tr>
<tr>
<td>B1</td>
<td>≥ 75</td>
<td>D2</td>
<td>≥300</td>
</tr>
<tr>
<td>B2</td>
<td>≥100</td>
<td>E1</td>
<td>≥340</td>
</tr>
<tr>
<td>B3</td>
<td>≥125</td>
<td>E2</td>
<td>≥380</td>
</tr>
<tr>
<td>C1</td>
<td>≥150</td>
<td>F</td>
<td>≥450</td>
</tr>
<tr>
<td>G</td>
<td>≥450</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 $T_b= 15.5^\circ C$ for heating and $T_b= 22^\circ C$ for cooling. The values are in the range between (110-120) kWh/m², 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 $T_b= 18.3^\circ C$ for heating and $T_b= 24^\circ C$ for cooling. The values are in the range between (110-120) kWh/m², 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 $T_b= 18.3^\circ C$ for heating and $T_b= 22^\circ C$ for cooling. The values are in the range between (120-140) kWh/m², 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 $T_b= 15.5^\circ C$ for heating and $T_b= 22^\circ C$ for cooling. The values are in the range between (120-140) kWh/m², 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 $T_b= 18.3^\circ C$ for heating and $T_b= 22^\circ C$ for cooling. The values are in the range between (145-165) kWh/m², 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 CO₂ 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<sub>occ</sub>**: The Cooling Load Factor for Occupants.
- **CLF<sub>lt</sub>**: The Cooling Load Factor for Light.
- **CLTD**: The Cooling Load Temperature Difference.
- **CLTD<sub>corr</sub>**: The Corrected Cooling Load Temperature Difference.
- **d**: Thickness.
- **DB**: Dry bulb temperature.
- **DD**: Degree-Days Method.
- **DD<sub>c</sub>**: Cooling Degree-Days.
- **DD<sub>h</sub>**: Heating Degree-Days.
- **F<sub>b</sub>**: Ballast Factor.
- **F<sub>u</sub>**: Fraction of Lamp That Are in Use.
- **HAP**: Hourly Program Analysis.
- **h<sub>i</sub>**: Inside Specific Enthalpy.
- **h<sub>o</sub>**: 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<sub>lt</sub>**: The Rated Power of the Lamps.
- **P<sub>r</sub>**: Rated power of the lamps.
- **q<sub><i>sen</i></sub>**: Heat Gain Rate.
- **q<sub>adj</sub>**: Heat Rate Transferred through partition.
- **q<sub>c</sub>**: Calculated Cooling load.
Design Energy Requirement for Conventional Cooling System.

Convection Heat Gain Rate Component Due to Glass Surface.

Heating Load Due to Infiltration.

Heat Gain

Calculated Heating load.


Heat loss.

Sensible Heat Gain Rate Due to Occupant.

Heat Gain Due to Solar Transmission

Thermal Resistance

Interior Surface Thermal Resistance.

The Conduction Thermal Resistance.

Exterior Surface Thermal Resistance.

Shading Coefficient Factor.

Solar Heat Gain Rate Factor.

Unconditioned Space Temperature.

Ground Temperature.

Inside Design Temperature.

The Average Maximum Monthly Mean Daily Temperature for Month.

The Average Minimum Monthly Mean Daily Temperature for Month.

Outside Design Temperature.

Outside Mean Temperature.

Unconditioned Space Temperature.

Over Heat Transfer Coefficient.

Volume of the Room.

The Specific Volume.

Wet bulb temperature.

The Air Density.

References


