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Energy Performance Analysis of Passive Design Strategies for the Green Affordable Homes Project in Jordan

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Abstract

With the aim to validate that green passive techniques are applicable, effective and affordable building solutions for low income community groups, this paper will study the impact of several passive design techniques on the overall energy performance on a residential building. This study presents energy analysis calculations for a small residential house located in Ajloun, Jordan. Which was designed for the Green Affordable Homes project in cooperation with Jordan Green Building Council (JoGBC). The energy analysis compares the house under three different construction scenarios; traditional construction techniques followed by the local community, Jordanian Energy Codes and the selected Green Affordable homes Project's standards. The mean of the energy simulation used is the Sefaria plug in for Revit Autodesk. Conclusions show that complying with the Jordanian thermal insulation codes is highly effective in energy savings resulting with approximately 70% reduction in the total energy loads when compared to traditional construction techniques. Furthermore, the most effective passive design strategy in terms of energy efficiency is the application of thermal insulation to external walls, by adding a 5cm insulation layer, a 16 % reduction in the heating loads was observed.

Key words: Sustainable Buildings Passive design, Energy saving, Revit Sefaria, Energy Analysis, Green Affordable Homes

1. Introduction.

Environmental sustainability of housing developments has drawn much attention in recent years, as one response to the global goal of attaining sustainable development (Stephen Pullen, 2009). The Queensland government's broad definition of affordable housing includes not just the initial housing cost criteria, but also other criteria such as meeting household needs (e.g. size and functionality) and being well located in relation to services, employment and transport (Queensland Department of Housing, 2001). In order to provide a long term affordable housing **solution, low** income housing should also have low long-term **operation costs** (Connie Susilawati, 2019)

Energy simulation of a building is helpful to analyze the movement of energy in, energy out, and through the rooms and volumes in a building model. This information is helpful for designers to make better analysis, cost-effective decisions that improve the building performance and reduce the environmental impact of buildings. Whole building energy analysis or simulation measures the expected energy use (fuel and electricity) based on the building's geometry, building type, climate, envelope properties, and active systems like HVAC & Lighting (Abhilash Jangalve)

This paper aims to demonstrate energy analysis calculations for a small residential house located in Ajloun, Jordan, which was designed for the Green Affordable Homes project in cooperation with Jordan Green Building Council (JoGBC). This study is based on a real life project implemented in Jordan, The Green Affordable Homes. The Green Affordable Homes project is carried by Jordan Green Building Council in cooperation with Habitat for Humanity as part of The Moving Energy Initiative. This project is funded by the UK's Department for International Development through the Moving Energy Initiative, with the aim of increasing sustainable energy access and resilience in refugee-affected areas.

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The main objective of the green affordable design and building strategies that were implemented in the design is to demonstrate that green passive techniques are applicable, effective and affordable building techniques for all community groups regardless of their income and social status.

1.1 Literature review

Applying energy efficiency methods in buildings have important benefits for the owner, the residents, the society and the environment. They can reduce operation costs, improve the image; they have low impact on the environment and most importantly, they cut the use of primary resources (Zancanella, P., Bertoldi, P., &Boza-Kiss, B. , 2018). A large amount of literature can be found on green building and energy efficiency methods. Lai and Wang (2011) conducted a study on Taiwan buildings to discover the most element that can reduce the energy consumption, they stated that the most effective factor in the energy-saving design of a Taiwan's building referred to thermal performance of booth the window glazing and the roof. Further, another study considered the performance of advanced envelope systems in UAE, Taleb (2016) stated that if green roofs and climatic interactive facade systems were applied it will reduce cooling thermal loads by 20%.

Some studies focused on revealing the cost of LEED Certified green buildings, as a study which was held in the US shown that LEED certification costs rise the total construction cost by 4–11% (The American Chemistry Council, 2003). On the other hand, another researches claim that the cost of green buildings is not greater than traditional buildings, they suggest that green features can be achieved with little or no added extra cost (Mapp, Nobe, Dunbar, 2011; Luay, Kherun, 2016).

Furthermore, Alshorman , Alrawashdeh, and Alshorman et al. (2017) investigated the validation of Jordanian green building model based on LEED standards through collecting data from four Jordanian cities, they reviled that the Jordanian green building model had achieved 69 points from the total 110 points, and from the LEED-nominal classification, this Jordanian green building model deserved the gold class. Nevertheless, limited studies outline the benefits of the Jordanian green building model, the current research attempts to fill this gap.

2.Method & Tools

The energy simulation tool used in this study is the Sefaria plug in for Revit Autodesk.

Sefaira creates cooling and heating design days from the imported weather file for each project based on guidelines in the ASHRAE 90.1 standard. The imported epw file was the Jerashfile created using meteonorm. Sefaira allows users to upload their own EnergyPlus weather files that are currently not available through our application or the weather files with the historical data for a particular location.

Sefaira's energy platform analysis uses EnergPlus as well as expert-designed HVAC templates based on ASHRAE standards to deliver the predicted energy consumption loads. The chosen system for the set of these energy simulations was DOAS: Fan Coil Units and Central Plant.

Provided that as a software specification, natural ventilation only works with HVAC systems that have a separate DOAS (Dedicated Outside Air System) for ventilation and zone units for heating and cooling. The specified HVAC system applied at the project creation, was automatically suggested by Sefaira, DOAS Fan coil system central Plant. Sefaira suggests a HVAC system based on the project's size, function (residential) and the climatic location (Jerashepw. File) be imported into the software.

The paper will present a set of analysis and comparisons in the energy consumption loads for a proposed layout (83m²) under three main different scenarios:

- Traditional construction method followed by local builders in ruler areas in Jordan (Traditional)
- Construction under the Jordanian energy code (JoCode)
- GAH Project Standards.

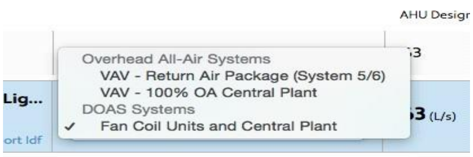

Figure 1HVAC System Input

Floor Plans and layout for the Revit Model
Traditional House

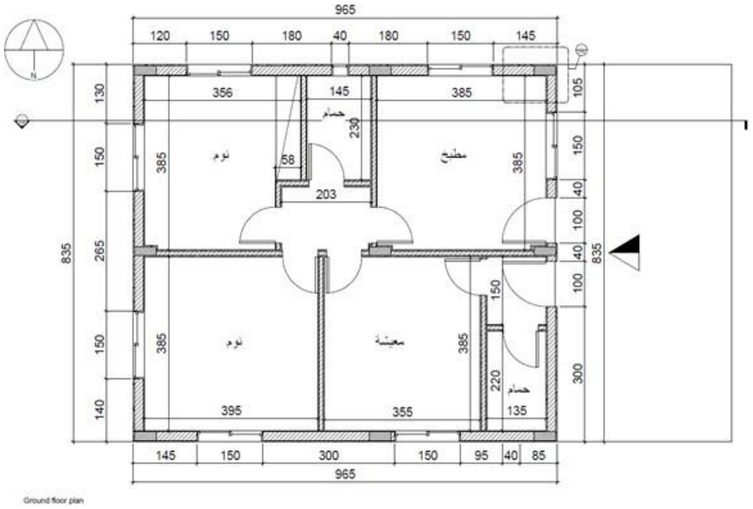

Figure 2Floor Plan for the digital model house

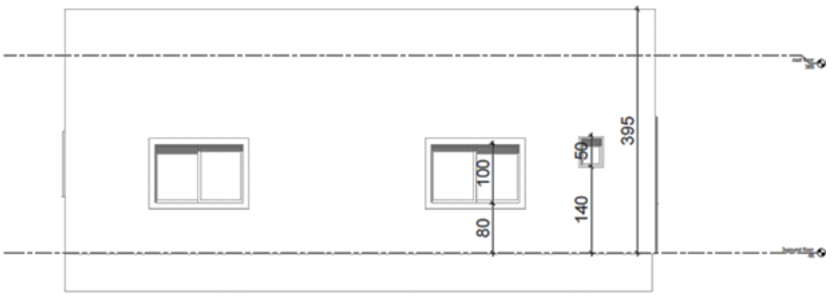

Figure 3 South Elevation of the Digital Modelled House

3. Results

Below is the table showing a summary of the input data used for the simulation process under the three main scenarios; Traditional, Jordanian codes and the parameters applied in the GAH project. It should be noted that the floor inputs of U-value = 1.2 w/m²k, remained constant throughout the entire simulations.

The first round of energy analysis simulations targeted the design strategies based on the building's exterior envelope, as well the electric lighting loads. The inputs were derived from, the conditions of the existing structure's traditional construction, the Jordanian building codes, and the green building codes. The three models simulated were: Baseline model (Traditional House), Alteration 01 (Jordanian building codes) and Alteration 02 (GAH Project Parameters).

Measure	**Traditional Construction**	**Complying with Jordanian Building Codes**	**Green Affordable Homes Project Measures**
External Wall	U-value =2.7 w/m²k	U-value =0.57 w/m²k	U-value =0.4 w/m²k
Floor	U-value = 1.2 w/m²k	U-value =1.2 w/m²k	U-value =1.2 w/m²k
Roof	U-value =1.56 w/m²k	U-value =0.55 w/m²k	U-value =0.4 w/m²k
Windows	Dimensions as layout	Dimensions as layout	Dimensions as layout
	Single clear glazing	Double clear glazing	Double clear glazing
	U-value = 5.7 w/m²k	U-value = 2.8 w/m²k	U-value = 2.8 w/m²k
Infiltration	Poor	Excellent	Excellent
Lighting	Fluorescent 18 W	LED 7.5 W	LED 7.5 W

Table 1 Value of Inputs for the Building Envelope Elements

With the aim of getting a slightly more accurate estimation of the building's heating and cooling loads under the three constructions methods: Traditional Construction used by local builder, Jo codes, and the GAH project adopted methods, simulations were run excluding the following zones, kitchen, toilets and the two spaces between the rooms.

This showed that a total of 47m2 of the space is heated during the winter months and cooled during the summer months.

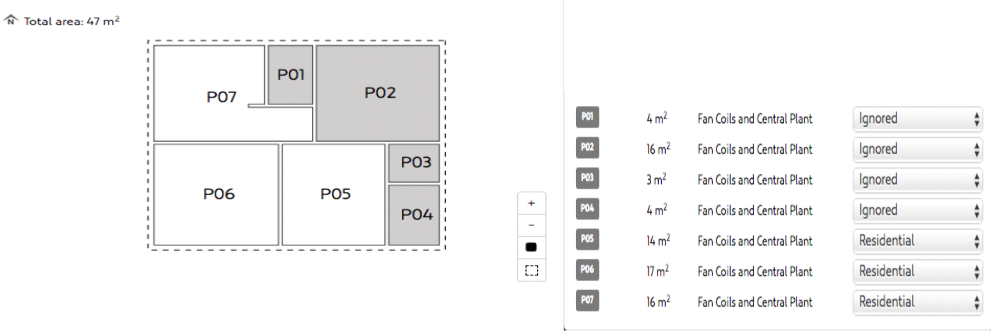

Figure 3 Areas covered in the Simulation Process

By observing the total change in the overall energy loads where all measures are applied there appears to be a 70% reduction in the total energy loads between the Traditional construction method and the Jo codes. See table 2.

Energy Loads	**Traditional Construction**	**Jo Codes**	**GAH Project**
Total Energy Loads	11,027 kWh/year	6,480 kWh/year	6,110 kWh/year
EUI per M2	233 kWh/m2 /year	137 kWh/ m2 / year	129/kWh /m2/year
Heating Loads	4,376 kWh/year	2,534 kWh/year	2,185 kWh/year
Cooling Loads	1,070 kWh/year	642 kWh/year	620 kWh/year
Lighting Loads	3,301 kWh/year	1,375 kWh/year	1,375 kWh/year

Table 2 Energy Saving Results

3.1Isolated Retro-fit Measures.

The second round of simulations run focused on the impact of each isolated retrofit measure in comparison with the baseline concept model (traditional houses). The isolated measure included the following: double-glazed windows, LED lighting, Natural ventilation, and the external shading devices.

Isolated Retrofit Measure	Impact on Energy loads
Double glazed windows 2.8 w/m²k	8 % reduction in the annual energy loads
LED lighting	4% reduction in the overall energy demand loads
Natural Ventilation	10 % reduction in the overall energy demand loadsز
External Shading Device 0.75 m	19% reduction in the overall energy demand loads.

Table 3Impact of Isolated Retrofit Measures

3.2Table of Results for LED as an isolated measure.

To individually analyze the impact of changing the fluorescent light bulbs to LED light bulbs, the lighting loads were analyzed as an isolated measure. The Type 1 basic construction model's lighting loads consumption only was simulated and compared to the same model with the change in the lighting equipment type.

Month	Total (kWh)	Total (kWh)
Annual Total	18234 kWh/year	17484 kWh/year
Overall Energy Loads	Reduction of 4%	

Table 4Total Annual Energy Savings

3.3 Discussion

Addition of Shading Devices

The design specification for the chosen shading device, followed the standard shading device calculation method, where the depth of the device is determined by multiplying the height of the window by 0.5 and the shading width extends a distance of 0.7m from the actual window on both sides. Therefore, the inserted shading device for this project was = 0.75Depth, 2.90 Width. The tested **shaded device in the simulations has shown an increase of 25% in the building's total winter months' heating loads along with a 32% reduction in the cooling loads and a 19% reduction in the overall energy demand loads.** Although the overall impact of the shading device on the energy loads is a positive reduction, the fact that the measure has caused an increase in the heating demand should be taken into account.

One solution can be the facilitation of the kinetic shading concept; where in this case it can be a moveable device that can be added during the summer month periods and removed during the winter. A simple form can be by planting deciduous trees, where they by nature leaf out to providing shade in the summer, and then shed their leaves in during the winter to let the sunshine in. (Gilmer, 2018)

A further study was undergone using the software climate consultant in order to analyze the optimum design solution for an exterior fixed shading device, which is determined by weighting the" shading" versus" heating" efficiency of the window-shade combination.

According to the sun shading chart the optimum vertical shadow angle (cast by horizontal shading devices) which the designed shading device should shade is 70 ° on the south elevation during the summer months. However, during the winter the angle is 45° on the southern façade. See the figures below. The design solution can either cover the winter shading requirement due to the fact that the building's heating loads are higher than the cooling loads or another solution can be to design moveable shading devices as suggested above.

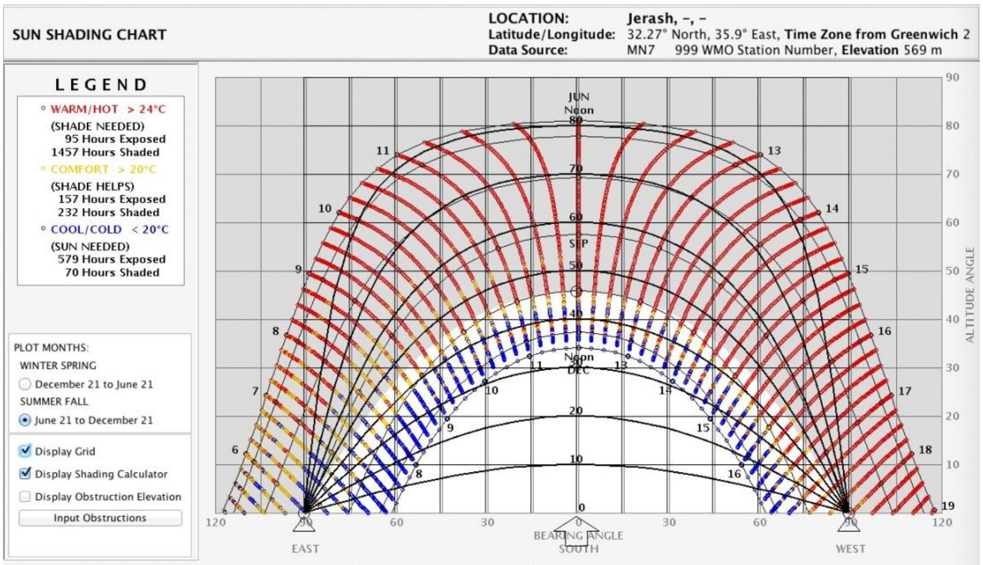

Figure 4Sun Shading Chart for summer months obtained from Climate Consultant for the epw. file of Jerash

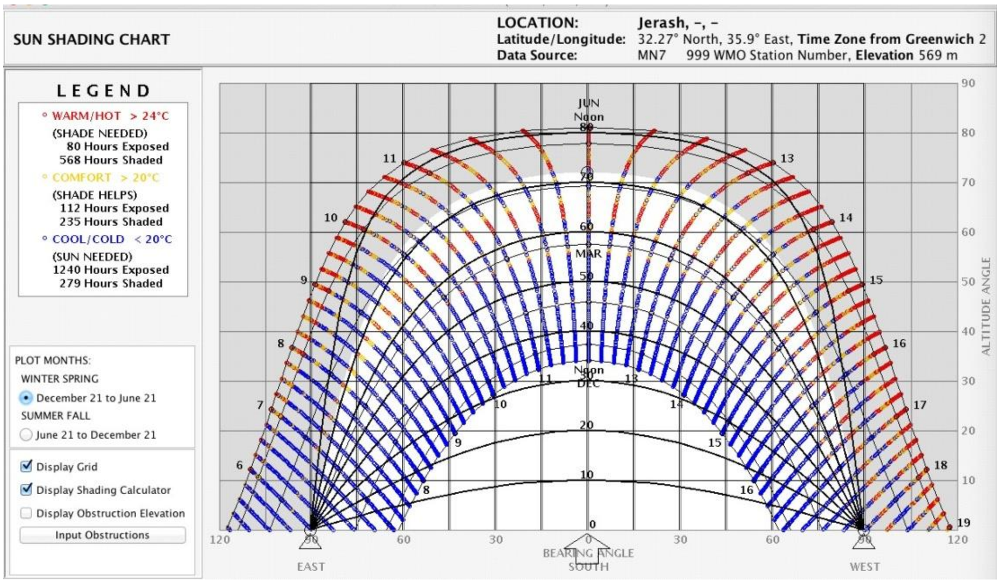

Figure 5 Sun Shading Chart for winter months obtained from Climate Consultant for the epw. File of Jerash

3.4Payback Calculations

The initial investments for each home type in Ajloun were obtained from the data provided by the Jordan Green Building Council which was created according to 2 local builders and Al Yanabea' CBO in Ajloun. The two types used in this section of the study are Type 3 representing the JO codes construction and Type 4 representing the applied measures in the GAH project.

Home Type	Type1 (The most basic)	Type 3	Type 4
Block layers	Single layer	Double layer	Double layer
3cm Thermal Insulation			
Walls		√	
Roof		√	
Floor		√	
5cm Extruded Polystyrene Thermal insulation (3JDs/m2)		3cm Extruded Polystyrene Thermal Insulation(2JDsm2)	
Walls *(86.05 m2)*			√
Roof *(80.16 m2)*			√
Floor		□	X
Waterproofing for Roof (5 JD/ M^2)	□	□	√
Double Glazing (17 JD per window)	□	□	√

Table 5 Model Types

**The above prices were estimated on April 2018, taking into consideration the dramatic drop in cement prices (from 108 JD/Ton to 42 JD/TON) due to sudden high competition movement between cement factories.

Payback Calculations

Adopted Methodology

Presented below is a payback calculation method that is conducted based on the data obtained from the simulated digital model presented in the analysis above. This section is based on the assumption that the dwelling above was operating and the results of the energy loads were paid following the Jordanian tariff policy. The loads will be taken for the excluded zones analysis, as it is not common for households to heat and cool toilets and kitchen spaces. It should be noted that lighting loads for those zones will be excluded from the calculations. However, provided that those are functional spaces and the amount of time that is spent there is not long, the conclusion is that it will not have a large impact on the building's total energy load consumptions.

Note: The presented table below uses the assumption that the entire building loads rely on electricity as an energy source. That is not the case in real life, however due to the fact that there is no one heating and cooling measure that is used in the sample studied houses in Ajloun

The electricity bills were calculated using an application called Jordan Electricity bill usage calculator. Where the monthly consumption in kWh is inserted and the total monthly bill based on the Jordanian electricity company's tariff, it should be noted that the HVAC system applied during the simulation process was the automatically suggested by Sefaira, DOAS Fan coil system central Plant. Sefaira suggests a HVAC system based on the project's size, function (residential) and the climatic location (Jerashepw. File) imported into the software.

ENERGY RESULTS –Annual Total						
Annual Total	**11023 kWh**	**1350.03 JDs**	**6478 kWh**	**536.02 JDs**	**6108 kWh**	**474.2 JDs**

Table 6 Total Cost Savings

3.5 Cost of Construction for each Housing Type

This Data was obtained from the Jordan Green Council, based on information from two local builders and Al Yanabea' CBO in Ajloun, the most common type is Type 2 with double 10 cm block layers and 3 cm of insulation is used for the walls (with no insulation for columns) and in many cases 3-5 cm gap is left between the 2 block layers. However for this exercise the traditional Construction type was simulated as the most basic type, Type 1.

The cost of construction between the Type 1 house and Jo Codes house is 9 JDs per Meter Square for the wall and 7JD per m2 for the roof plus the additional cost of 17 JDs per window for double- glazing.

Traditional Codes & Jo	**Annual Energy consumption Loads With Excluded Zones**	**Annual Bill**
Baseline Traditional	11023 kWh	1350.03 JDs
JO-Codes	6478 kWh	536.02 JDs
Difference	70%	814.01 JDs

Table 7 Impact Savings of the Application of all Methods

Cost of Investment in Jo Codes = 1454.57JDs (Wall & Roof Insulation + 17JDs*7 Dbl. glaze Windows)
5,936 JDs / 814 JDs = 1.78years
Therefore, the payback time is approximately 2 years.

Jo Codes & GAH Measures	**Annual Energy consumption Loads With Excluded Zones**	**Annual Bill**
Jo Codes	6478 kWh	536.02 JDs
GAH Measures	6108 kWh	474.2 JDs
Difference	6%	64.82

Table 8 Impact of 5cm Insulation

Cost of Investment in the suggested GAH measures = 166.21 (5cm insulation) 166.21/64.82 = 2.56
Therefore the payback time is approximately 2.5years

Isolated Measures – Double Glazed

Double glazed Windows	**Annual Energy consumption Loads**	**Annual Bill**
Baseline Traditional	18609 kWh	3193.95 JDs
Dbl. Glazing	17189 kWh	2809.13 JDs
Difference	8%	384.82 JDs

Table 9 Results for Double Glazing

A sample family was taken as a sample case of study to calculate an assumption of the payback period for the methods. By looking at the Energy Analysis chart performed as a study covering a sample, one family appears to rely on electricity for its winter heating supply. The annual bill for this family is 350JDs. With the average monthly summer bills costing 18 JDs / month and the winter monthly bills JDs /month.

Dbl. Glazed Windows		
	Annual Energy consumption Loads	**Annual Bill**
Baseline Traditional	18,609 kWh/year	350 JDs
Dbl. Glazing	17,187 kWh/year	322JDs
Difference	8%	28 JDs /year
Cost of Investment in Dbl. Glaze	17*7= 119JDS	

Figure 6 Annual Energy savings for Double glazing

Where119/28 = 4.25 years thus the payback period of the Installation of the Double-glazed windows is around 4 years and a few months

Isolated Measures – LED Light Bulbs Instalments

LED bulbs VS. Fluorescent

	Annual Energy consumption Loads	**Annual Bill**
Baseline Fluorescent	18,234 kWh/year	350 JDs
LED Bulbs	17,484 kWh/year	336
Difference	4%	14 JDs /year
Cost of Investments in LED lamps	11X5= 55 JDs	

Figure 7 Annual Energy savings for LED Bulbs

55/14 =3.92 thus the payback period of the instalment of LED bulbs (11 bulbs) is **4 years.**

Retrofit with all Measure - Shading, Dbl. glazed Windows, LED Lights

Traditional & Retrofit Measures		
	Annual Energy consumption Loads With Excluded Zones	**Annual Bill**
Baseline Traditional	11023 kWh	1350.03 JDs
Applied Retrofit Measures	9,437	1134 JDs
Difference	16 %	216 JDs
Cost of Investment in the mentioned measures	224 JDS	

Figure 8 Annual Energy Savings for all measures combined

Where 224/216 =0.96 thus the payback period of the application of the proposed retrofit strategies for the GAH project versus the traditional construction is about 1 year.

Comparing the Application of all the GAH Measure with the Traditional Construction Methods

Traditional & GAH Project Measures		
	Annual Energy consumption Loads With Excluded Zones	**Annual Bill**
Baseline Traditional	11023 kWh	1350.03 JDs
Applied GAH Measures	6108 kWh	474.2 JDs
Difference	80%	1080
Cost of Investment in the GAH project proposed measures	**6767.05 JDs**	

Figure 9Comparing Traditional Methods and GAH Project Measures

Where 6767.05/1080 thus the payback period of the application of the proposed **retrofit strategy is**

about 6 years.

4. Conclusion

Several green passive techniques on energy performance on a small residential building were calculated and compared under three construction scenarios: traditional construction, Jordanian Energy Codes and Green Affordable homes Project standards to attain sustainable development with long term operation costs for low income housing. The energy simulations for several elements were calculated and analyzed to show the following results. Exterior building envelope and electric lighting loads were tabulated for the three constructions. Analysis 1 examining excluded zones within the energy simulations and showed 47m2 was modified – living area and two bedrooms. These showed a high 70% reduction in energy loads between traditional and Jo code constructions, between Jo and GAH only 6%. However, with heating loads an additional 5cm of insulation showed 16% heating load reduction and 3% decrease in cooling loads.

Analysis 2 was on the impact of isolated retrofit measures on energy loads of double glazed windows (8%), LED lighting (4%), natural ventilation (10%) and external shading devices (19%).

Analysis 3 on insulation demonstrated 3cm insulation reduced consumption by 16% where 5% insulating layer reduced it by only 2% compared with the traditional house.

Simulated shading showed an increase of 25% in total winter heating with a 32% reduction in cooling and a 19% reduction in overall energy demand loads. Deciduous trees are recommended or moveable shading devices. Payback was calculated for initial investment using electricity showing 1350 JD for a traditional house, 536 JD for Jo and 474 JD GAH, ie. The Jo code was the best value. Regarding cost of construction for each housing type: Type 1 compared with Jo had a payback time of 1.78 years, Jo compared with GAH was 2.56 years.

Examining isolated measures: investment in double glazing cost 119JD for building or it would be paid back in under a year, with a payback period of just over 4 years for retrofitting. LED lightbulbs also were paid back in 4 years. All three- shading, double glazing and LED lights retrofitted would cost I year to payback in a traditional home; traditional with GAH retrofitting would take 6years.Conclusions show that the best value is to build or retrofit according to the Jordanian Energy Code building measures.

According to Table (2) The simulation results show a 70% reduction in the overall energy loads of the building where this includes (Heating, cooling, equipment, lighting and pumps) the equipment, and the pump input measures remained constant throughout the entire simulations. The zones included in the simulations are the two bedrooms and living area. The difference between the total energy loads between the JO codes and the GAH Measures is extremely low with a 6 % reduction. On the other hand, with the heating loads as a separate measure the addition of a 5cm insulation layer shows a 16 % reduction in the heating loads of the dwelling and a low decrease of 3% in the cooling loads.

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