التعديل التحديثي للطاقة لمبنى سكني باستخدام نموذج معاير في مناخ البحر المتوسط

Energy Retrofit for a Residential Building Using a Calibrated Model in a Mediterranean Climate

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Abstract

Developing countries face several challenges concerning energy provision. This is more urge in conflict zones like Palestine due to the political instability. The energy shortage is coupled by the unsustainable consumption of energy attributable to the poor quality of housing in terms of thermal performance. The main goal of this paper is to estimate the energy savings through retrofitting of the building envelop using a calibrated model of an apartment in the city of Hebron, West Bank, Palestine. A case study apartment was chosen as a prototype of apartments in Hebron. Physical survey was performed. Then, data concerning user's behaviour during summer and winter; systems usage and patterns of occupying the rooms was collecte

d via semi structured interviews with the occupants. The goal was to understand the users behaviour and to integrate it when building the model to reflect the actual usage of the building. In situ measurements (two monitoring phases) of the internal and external temperature using data loggers were taken. The calibration of the model depended on ASHRAE standards and graphical calibration for thermal simulation models validation. Optimization of the building envelope components was made through Dynamic Energy Simulation (DES) using IESVE software. The results of the paper show that the amount of energy that can be saved through retrofitting of the building envelop of the existing building stock can reach up to 79.0% of the heating and 55.0% of the cooling energy.

[The second-place winning research in the field of engineering in the 38th competition of the Rashid Bin Humaid Prize for Culture and Science]

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ملخص

تواجه البلدان النامية العديد من التحديات فيما يتعلق بتوفير الطاقة. هذا أمر أكثر إلحاحًا في مناطق الصراع مثل فلسطين بسبب عدم الاستقرار السياسي. يقترن نقص الطاقة بالاستهلاك غير المستدام للطاقة الذي يُعزى إلى رداءة نوعية المساكن من حيث الأداء الحراري. الهدف الرئيسي من هذه الورقة هو تقدير مدخرات الطاقة من خلال تعديل غلاف المبنى باستخدام نموذج معاير لشقة في مدينة الخليل ، الضفة الغربية ، فلسطين. تم اختيار شقة دراسة الحالة كنموذج أولي للشقق في الخليل. تم إجراء المسح المادي. ثم البيانات المتعلقة بسلوك المستخدم خلال الصيف والشتاء ؛ تم جمع استخدام الأنظمة وأنماط احتلال الغرف من خلال مقابلات شبه منظمة مع شاغليها. كان الهدف هو فهم سلوك المستخدمين ودمجه عند بناء النموذج ليعكس الاستخدام الفعلي للمبنى. تم أخذ قياسات في الموقع (مرحلتان مراقبة) لدرجة الحرارة الداخلية والخارجية باستخدام مسجلات البيانات. تعتمد معايرة النموذج على معايير ASHRAEوالمعايرة الرسومية للتحقق من صحة نماذج المحاكاة الحرارية. تم تحسين مكونات غلاف المبنى من خلال محاكاة الطاقة الديناميكية (DES) باستخدام برنامج IESVE.تظهر نتائج الورقة أن كمية الطاقة التي يمكن توفيرها من خلال التعديل التحديثي لغلاف المبنى لمخزون المبنى الحالي يمكن أن تصل إلى 79.0٪ من التدفئة و 55.0٪ من طاقة التبريد.

[البحث الفائز بالمركز الثاني في مجال الهندسة بالمسابقة الـ38 لجائزة راشد بن حميد للثقافة والعلوم]

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Introduction

One to of the key prerequisites for the economic prosperity and the social wellbeing in developing countries is to have an adequate access to modern energy. Most of the energy resources in Palestine are procured through Israel, making energy not only unaffordable to many Palestinians but also insecure which impacts the residents' safety, thermal comfort, health and wellbeing. A tremendous energy demand in the Palestinian Territories in recent years was created by population growth, increasing living standards and rapid industrial growth. The Palestinians in the West Bank and Gaza consumed 23,300 barrels of petroleum per day (bbl/d) in 2012 [1]. On the other hand, The Palestinian energy sector, like all other economic sectors, is controlled by Israel making it less secure [2]. Almost all energy resources, including electricity, are imported through Israeli companies and distributed to Palestinian consumers by national suppliers, with the exception of wood [2]. Despite the challenges the energy sector faces in Palestine, the location and climate provide a valuable opportunity for the use of renewable energy sources. The daily average solar radiation in Palestine is 5.4 kWh/m^2 and has the potential for mass application [3]. Rational investment in renewable energy needs to be preceded by energy optimisation. In Palestine, the residential sector is a main consumer of energy [4]. This sector should be among the targeted sectors in any energy policy attempting to encourage sustainable energy technologies [5,6,7].

Therefore, there is a crucial requirement to enhance the thermal performance and optimize the energy consumption considering the occupants behaviour [8]. This paper investigates the energy savings for heating and cooling of residential buildings with specific reference to Palestine. A case study apartment in a residential building in Hebron is used to verify the developed approach of energy optimization. The model was first calibrated based on ASHRAE standards using internal environment measurements that were recorded over two monitoring phases the first was between 12th Oct -1st Nov 2017 and the second was between 28th Jan -10th Feb 2018. Data loggers was used collect the environmental parameters.

Research Method

The research adopted a mixed method approach [9] combining several qualitative and quantitative techniques for data collection and analysis. The existing building stock consumes a considerable amount of energy for heating and cooling [10]. A case study apartment in a residential building was selected as a prototype model for the residential apartment in Hebron. The building is located to the north of Hebron. It is consisted of six floors with three apartments in each. The case study apartment is in the fourth floor and is open from three facades to the north, east and west. The apartment was occupied by early thirties working married couple.

- Building the basic (DES) model

Physical survey was performed for the apartment defining the building materials and the plan was drawn as can be seen in Figure 1. Then, a semi structured interview was performed with the occupants to understand their behaviour and the occupancy pattern of the different rooms during summer and winter. Semi structured interviews was used as it allows the researcher to prepared the questions in advance and also collect open-ended data and to explore participant thoughts. The interviews covered the use of the different systems in the house such as the heating and cooling, appliances such as stove in addition to the frequency of opening the windows and the external shutters. This was done in order to be included during the modelling phase of (DES) using IESVE to reflect the actual use of the building. Figure 2 illustrates the occupancy in different rooms in the apartment during a typical weekday as modelled depending on the data gathered from the interview. The heating and cooling systems that were used in the apartment were electric heater and electric fan. These two were modelled as an internal gains and losses, taking into account the pattern of usage to make sure that the basic model performs similar to the real building.

Monitoring is a method that is used to have an in-depth understanding of the thermal behaviour of buildings [11,12]. In order to validate the base (DES) model that was created via IESVE, environmental data (air temperature and Relative humidity (RH)) were gathered using data loggers on two phases. Calibrated Extech RH10 loggers (±0.1°C) were used as part of the monitoring phase to assess the actual operational performance of the dwellings [13]. Two data loggers were used for monitoring, one inside the dwelling and one outside with a time interval of 5 minutes was set for each. The data loggers were set about 150 cm above the ground and away from any direct source of heat, coldness or sunlight. They were also concealed to decrease their effect on the households' behaviour. The outdoor data logger was set on a windowsill of the single house on the northern façade, away from direct sunlight.

Figure1: Apartment floor plan

Since the collected data will be used to calibrate the model developed using IESVE, the longitudinal approach was adopted and monitoring covered two periods [14,15]. The first reading set was collected between 12th October and 1st November 2017, while the second set was collected between 28th January and 24th February 2018. One of the limitations of the study was that it was difficult to send the data loggers to Palestine and collect more data through monitoring. After each monitoring period, the data loggers were collected, and the monitored data downloaded into an Excel sheet. The building geometry was built using Revit software then exported to IESVE where the location, orientation, weather file, building materials and the systems used were assigned based on the gathered data from the physical survey and the semi structured interviews. Table (1) shows the materials assigned for the (DES) model with the calculated thermal conductivity and thermal mass.

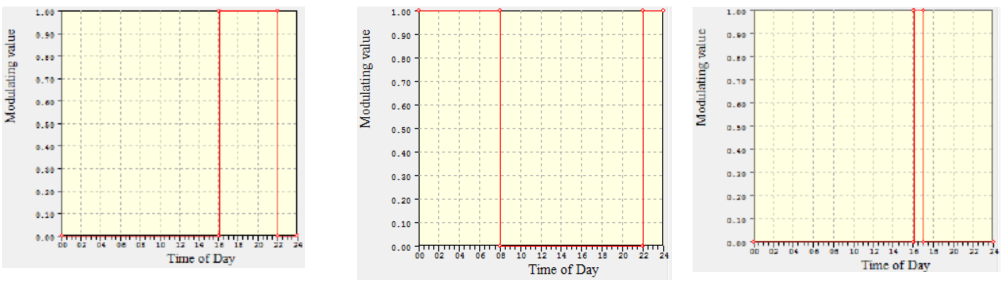

Figure2: Occupancy profile in the Livingroom, kitchen and main bedroom respectively

Table 1: Building's components specifications

Building component	**Materials used**	**U value (W/m^2k)**	**Thermal mass ($kg/(m^2.K)$)**
External walls	Stone 7, concrete 15, concrete hollow blocks 7, plaster 1.5	2	143.8
Ground	Reinforced concrete20, concrete baking8, sand 5, mortar 2, concrete tile 2	1.5	175.7
Roof	Waterproof membrane 0.3, concrete baking 8, bricks and ribs 17, plaster 1.5	1.7	108.4
Ceiling	Concrete tiles 2.5, mortar2.0, sand 2.0, concrete baking 8, bricks and ribs 12, cement plaster 1.5	2.4	146.7
Internal walls	Plaster1.5, concrete hollow blocks 7, plaster1.5	2.7	74.6
External doors	Iron 0.5, cavity 1.5 , iron 0.5	5.7	---
Glazing (g) value 0.5, transmittance (T) 0.7	Single glazing	5.7	---

There are two general approaches when modelling the occupancy pattern in the residential sector: the individual approach and the family approach. The first approach obtains occupancy data based upon national survey data of people's time-use distributions, while the second relies on data regarding a family's schedule, based on the most common household occupancy patterns [16]. Because tracking down detailed information for individual occupant is difficult, the ‘family’ approach is adopted in this study. Figure 3 shows the occupancy profile in the apartment during a typical weekday by the family.

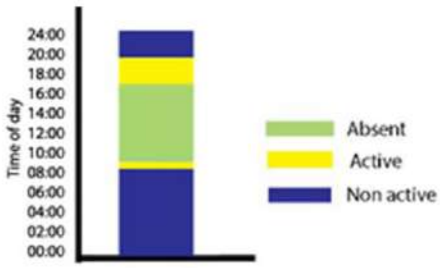

Figure3: Occupancy profile in the apartment

The household used fluorescent lighting, estimated as 17W/m^2. The lights in the living room are usually turned on between 17:00 till 20:30 and then for about half an hour in the bedroom. There is one TV unit in the living room, which is turned on between 18:00-20:00. The fridge in the kitchen is on continuously while the cooker is used for about an hour during the late afternoon.

The heaters were on during the months indicated by the households (15th November-30th April) and were off during the rest of the year. The different heating systems were assigned based on the data gathered from the interview. For example, an electric heater is used in the reception area with a wattage of 1200W was used during the heating season between 16:00-22:00 each day. For cooling, a fan is used. The cooling pattern was developed on a daily profile, and then a weekly and yearly profile was developed. In summer, the fan worked for two hours between 15th June -15th August and was off during the rest of the year.

- **Validation of the (DES) model**

There are always discrepancies between simulation outcomes and real data [17]. In order to improve the accuracy of the DBPS model results to energy optimization, calibration is needed (18). Calibration (validation) is to approximate the DBPS model results to the real data as closely as possible [19].

Four main categories of calibration methodologies were presented by [20]: manual; graphical-based; calibration based on special tests; and analysis procedures and automated techniques.

During the calibration process of a certain model, different methods from the four categories above, can be used depending on the purpose of modelling; the configurations of the 158 systems in the building; availability of data; and level of experience [21,22]. In this paper, the manual and graphical methods were used.

Energy simulation models for predicting energy consumption are considered 'calibrated' if they meet the criteria set out by ASHRAE Guideline 14 [23]. The protocol for energy calibration defines two statistical measures to determine the fitness of the model. The first is the Mean Bias Error (MBE) to be 10% and the Coefficient of Variation of Root Mean Square Error CV(RMSE) to be 30% for the hourly readings.

For this research, the data gathered from the two case studies is the monitored internal temperature in addition to the annual consumption of energy used for heating and cooling. The users explained that they use more than one energy source used for heating including electricity and LPG heaters which is a common practice in the research context. Moreover, no smart meters are available. Hence, the total amount of energy was calculated based on the frequency of using the systems. Since no energy meter readings were involved so the calibration of the models was based on the internal monitored temperature. This approach was used in other similar research where energy readings were not available [24,25]. Since there are no specific standards for calibration using the measured temperature, research based on calibrating a buildings' temperature relies on the same energy validation protocols [25].

Three rounds of calibration were performed, based on the monitored internal temperature readings in the two monitoring periods (12th Oct -1st Nov 2017 and 28th Jan -10th Feb 2018). The building material values were input using the local Energy Efficient Building Code [26] and other values were based on the operator's judgment, such as the infiltration rate. In the first round, all schedules are as expressed by the users or observed by the researcher. In the second round, the envelope (external walls U-value) was increased, by increasing the conductivity rate, using the maximum value limits presented in the local Energy Efficient Building Code [26]. The thickness of the walls was considered constant. Table 2 shows the external walls' conductivity and U value parameters that were changed in the second round of simulation.

Table 2: External wall thermal characteristics used in calibration

		Stone	Concrete	Concrete blocks	Plaster
Conductivity	Old value	1.3	1.0	0.7	0.25
	New value	2.2	1.2	1.0	0.75
U value ($W/m^2.k$)	Old value	1.53			
	New value	2.01			
Thermal mass (J/K)	Old value	790			
	New value	812			

In the third round the infiltration rate was increased from 3 to 5 ach and the MBE, RMSE and CV(RMSE) were calculated for each of the rounds [27]. Table 3 presents the three calibration rounds including these values for each of the calibrated rooms and the overall weighted value.

Table 3: Characteristics of the three calibration rounds including NMBE, RMSE and CVRMSE

		Calibration characteristics		
		Round 1 (red)	**Round 2 (green)**	**Round 3 (blue)**
		HL 1.6 kWh CL 0.014 kWh U value 1.53 Infiltration rate 3.5 ach	**HL 1.6 kWh CL 0.014 kWh U value 2.01 Infiltration rate 3.5 ach**	**HL 1.6 kWh CL 0.014 kWh U value 2.01 Infiltration rate 5**
Guestroom (n= 4030)	NMBE	1.215821	-3.38083	-3.20197
	RMSE	2.01907	2.387962	2.299965
	CV(RMS)	15.59174	18.44041	17.76087
Guestroom (n= 2894)	NMBE	4.230516	0.219816	0.18785
	RMSE	1.439116	2.236973	1.911669
	CV(RMS)	7.607527	11.8252	10.10556
Weighted	NMBE	2.475863	-1.87588	-1.78514
	RMSE	0.601857	2.324854	2.13767
	CV(RMSE)	12.25461	15.67547	14.56121

In the first round, simulated temperature was considerably higher during the two periods of monitoring. In round two, the U-value of the external walls was increased from 1.53 to 2.01. Figures 4 and 5 shows that in the second round the temperature simulation was lower and closer to the monitored data. In the third round, the infiltration rate increased from 3.5 to 5 ach; the simulated temperature in the guestroom shown good statistical values; and the number of matching values increased. The weighted metrics of the two rooms are within acceptable ranges: 14.56% for CVRMSE and -1.78% for NMBE. Based on the statistical metrics and the graphical illustration of the simulation, the model can be considered calibrated.

- Energy optimization

As explained by (28), the optimisation process consists of a set of free parameters (the independent variables or design parameters), certain restrictions that bound the domain of the free parameters and dependent variables, and finally an objective (to be minimized) that depends on the design parameters [28].

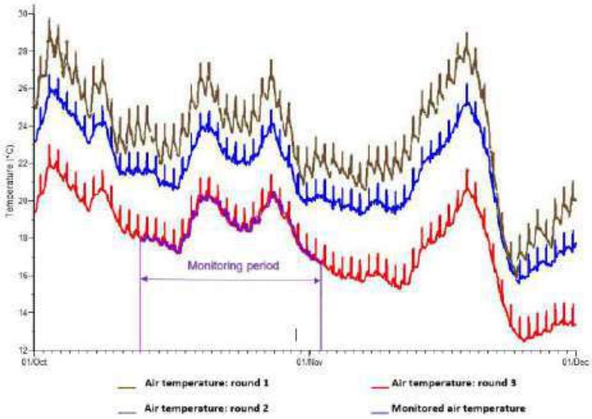

Figure 4: Simulation results of the three rounds and the monitored temperature in the guestroom for the period 12th October-1st November/2017

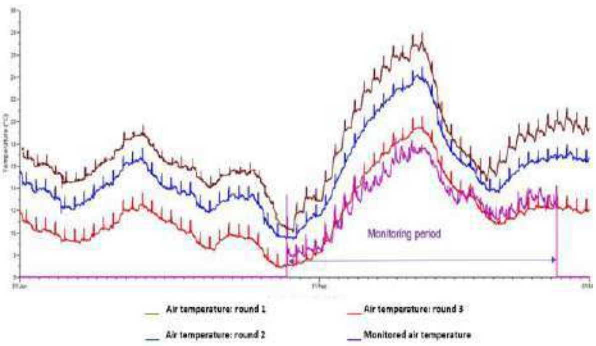

Figure 5: Simulation results of the three rounds and the monitored temperature in the guestroom for the period 28th January-24th February/2018

The main goal of the optimization is to define the optimal design [29]. Numerous studies have been conducted on the optimization of building performance [30,31,32]. Optimisation can be performed for a building as a whole system [33,34], or for certain parts of the building, such as shading devices [35] and wall insulation [36]. Furthermore, energy optimisation can take place in different phases of the building’s life: in the early design stages [37,38,39] for retrofitting measurements of existing building [40,41,42,43]; and for the lifecycle of the building [44]. There are several approaches to the energy optimisation in buildings, including statistical analysis [45] and building energy performance simulation (DBPS) [46,32].

The optimization was conducted by (DBPS) using IESVE software to assess the impact of the envelope design. The objective is to reduce the energy consumption when heating and cooling the space. The simulation was done for single interventions and combined interventions.

The current actual performance of the buildings was used as a baseline to define the potential energy savings strategies. It is important to mention that the ApacheSim in IESVE takes into consideration the nearby buildings that were modelled. However, the impact of the further buildings is not considered.

For optimization, air conditioning systems were used in the occupied rooms. The heating and cooling system was assumed to work during the occupancy duration in the period 15th November-30th April. The cooling system was assigned to work during 15:00- 22:00 hrs between 1st July-31st August. The baseline of the annual heating and cooling energy and the heating and cooling set points are illustrated in Table 4.

Table 4: The baseline heating and cooling loads of the design parameters

Heating set point during winter (°C)	**Annual heating loads (kWh)**	**Cooling set point during summer(°C)**	**Annual cooling loads (kWh)**
21	5623.0	24	332.0

- Opaque elements insulation and thermal mass

This part examines the effect of thermal insulation and thermal mass of opaque elements on the building's envelope performance. Optimization covers the external walls, ceiling, internal walls and external doors. Since the apartment is in the middle of the building on the fourth floor, no optimization was considered for the ground or roof in this case, as suggested by the software.

a. External wall optimisation

Table 5 presents the different external walls configurations that were examined, their thermal transmittance (U-value) and thermal mass k. The simulation results show that the impact on heating is substantial in all cases. The highest impact on both heating and cooling loads was in EXWC7, EXWC8 and EXWC9 equally with a heating saving of 12.5% and cooling savings of 2.7%.

b. Ceiling optimisation

Ceiling insulation is not a common energy efficiency practice when the upper and the lower spaces have similar indoor temperature, as in the case of this model. However, ceiling insulation is useful also in terms of acoustics, which is an important issue in residential buildings. Table 6 shows the ceiling composition as examined for energy optimization.

Decreasing the U-value from 50% to 75% in CC1 and CC2 had no discernible effect upon the heating energy savings, but savings in terms of cooling energy increased to 2.0%. When applying CC3, heating saving increased slightly to 0.8%, while the cooling energy savings were 2.2%, with a total saving of 0.7%. It is obvious that the impact of the ceiling insulation on energy saving is negligible because of the way the ApacheSim assumes that the adjacent buildings have the same internal temperature with no heat transfer taking place. However, when the spaces above and below are not heated or cooled, as in many cases in Hebron, ceiling insulation is an important energy efficiency measure to limit heating loss. This measure can be applied when constructing new buildings. In existing buildings, insulation can be added inside and covered with gypsum boards.

Table 5: External wall configurations for optimization

No.	**Configuration (outside to inside) (cm)**	**U value (W/m^2K)**	**Thermal mass (kj/m2.k)**
EXWC1	Stone (7), extruded polystyrene (1.4), concrete (15), concrete hollow blocks (7), plaster (1.5)	1.2, (Decreased by 50%)	149.0 (Medium weight)
EXWC2	Stone (7), extruded polystyrene (4), concrete (1.5), concrete hollow blocks (7), plaster (1.5)	0.61, (Decreases by 75%)	149.0 (Medium weight)
EXWC3	Stone (7), extruded polystyrene (8), concrete (1.5), concrete hollow blocks (7), plaster (1.5)	0.35	149.0 (Medium weight)
EXWC4	Stone (7), concrete (15), extruded polystyrene (8), concrete hollow blocks (7), plaster (1.5)	0.35	117.5 (light weight)
EXWC5	Stone (7), concrete (15), concrete hollow blocks (7), extruded polystyrene (), plaster (1.5)	0.35	19.5 (very light weight)
EXWC6	Stone (7), concrete (15), air gap (15), concrete hollow blocks (7), plaster (1.5)	1.6	117.5 (light weight)
EXWC7	Stone (7), extruded polystyrene (8), Aluminium foil 0.05 emissivity (0.2), concrete (15), concrete hollow blocks (7), plaster (1.5)	0.35	149.0 (Medium weight)
EXWC8	Stone (7), Aluminium foil 0.05 emissivity (0.2), extruded polystyrene (5.5), Aluminium foil 0.05 emissivity (0.2), concrete (15), concrete hollow blocks (8), plaster (1.5)	0.35	149.0 (Medium weight)
EXWC9	Stone (7), Aluminium foil 0.05 emissivity (0.2),	0.35	149.0 (Medium weight)

	extruded polystyrene (8 mm), concrete (15), concrete hollow blocks (7), plaster (1.5)		

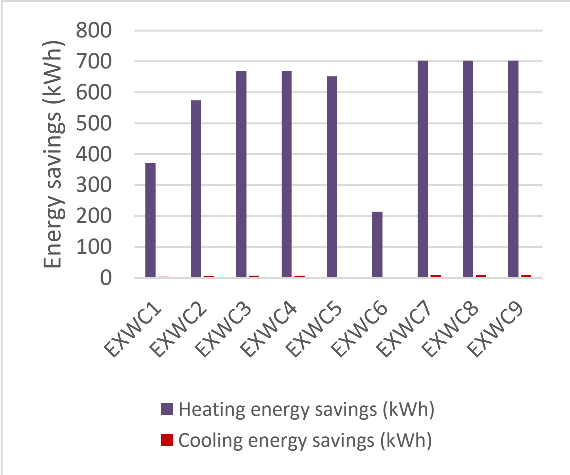

Figure 6: The results of external wall optimisation

Table 6: External wall configurations for optimization

No.	Configuration (outside to inside) (cm)	U value (W/m^2K)	Thermal mass ($kj/m^2.K$)
CC1	Concrete tiles (2.5), mortar (2.5), sand and gravel (2), insulation (1.2), reinforced concrete (20), plaster (1.5)	1.27 (Decreased by 50%)	149.0 (Medium weight)
CC2	Concrete tiles (2.5), mortar (2.5), sand and gravel (2), insulation (7.5), reinforced concrete (20), plaster (1.5)	0.63, (Decreases by 75%)	149.0 (Medium weight)
CC3	Concrete tiles (2.5), mortar (2.5), sand and gravel (2), insulation (1.1), reinforced concrete (20.), plaster (1.5)	0.25	149.0 (Medium weight)

c. Internal walls optimization

The composition of the internal walls that were examined for energy optimization can be seen in Table 7. Using the configuration INW1 (very light weight) will have save the heating and cooling energy of 4.0% and 1.5% respectively. When the U-value was decreased by 75% (light weight), the energy savings increased to 6.6% for heating and increased slightly for cooling to 1.7% using INW2. INWC3 complies with the PGBG and it can save 7.3% of heating energy and 1.8% of cooling energy.

d. External doors optimisation

The external doors' configuration are shown in Table 8 including the heating and cooling energy savings. Increasing the U-value of this door had a positive impact on both cooling and heating energy savings, but the savings did not exceed 2% of the total energy.

Table 7: Configuration of internal walls for optimisation

No.	**Configuration (outside to inside)**	**U value (W/m^2K)**	**Thermal mass (kj/m2.k)**
INW 1	Plaster (1.5), concrete hollow blocks(7), insulation (1), gypsum board (1), plaster (1.5)	1.29, (Decreased by 50%)	92.7 (very light weight)
INW 2	Plaster (1.5), concrete hollow blocks (7), insulation (3.7), gypsum board (1), plaster (1.5)	0.62, (Decreased by 75%)	111.4 (light weight)
INW 3	Plaster (1.5), concrete hollow blocks (7), insulation (5.8), gypsum board (1), plaster (1.5)	0.45	121.4 (light weight)

Table 8: Configuration of external walls for optimisation

No.	**Configuration (outside to inside) (cm)**	**U value (W/m^2K)**	**Total energy savings (kWh)**
EXD1	Hot cast iron (1), cavity (1.2), cast in place iron (1)	2.8 (reduced by 50%)	93
EXD2	Hot cast iron (1), insulation (1.6), cast in place iron (1)	1.5	93
EXD3	Hot cast iron (1), insulation (2.7), cast in place iron (1)	1.0	93

- Fenestration design

This part will illustrate the impact of upgrading the transparent elements of the building. The focus will be on windows in the context of U-value, g-value and transmittance (vt). Since the number of simulations that can be done is huge, the researcher has limited the options to five cases among the products that can be sourced in local markets or neighbouring countries. Table 6.17 shows the characteristics of the different glazing systems that were used for optimization.

The impact on heating and cooling energy is plotted for each glazing system and shows that the greatest saving for heating energy is achieved via GLC5 at 1.7%, followed by GL4 at 1.6% and GL3 at 1.55%. For cooling energy, the saving is equal in GLC3, GLC4 and GLC5 at 0.4%. Since the extra saving is very small and since using argon instead of air will add a considerable cost and maintenance, the preferred option in this case was GLC3.

Table 9: Configuration of internal walls for optimisation

No.	**Configuration (outside to inside)**	**U value (W/m^2K)**	**(g) value**	**Visible light Transmittance (vt)**
GLC1	Double glazing (air) PGBG visible light transmittance 0.71, g value 0.3256	1.9	0.3256	0.71
GLC2	Double glazing (air) PGBG visible light transmittance 0.25, g value 0.4	1.9	0.4	0.25
GLC3	Triple glazing (air), visible light transmittance 0.71, g value 0.2356	1.3	0.3256	0.71
GLC4	Double glazing (argon), visible light transmittance 0.71, g value 0.3256	1.6	0.3256	0.71
GLC5	Triple glazing (argon), visible light transmittance 0.71, g value 0.3256	1.1	0.3256	0.71

- Airtightness

The natural ventilation pattern was variable, especially during summer, and the windows were closed when using the cooling system. The airtightness was examined by first reducing the infiltration rate from 5 ach to 3 ach, and then to 2.7 ach which is the infiltration rate recommended by the PGBG.

The simulation results show that airtightness plays the most important role among the examined measures when it comes to energy savings. A difference of 0.3 ach between the two options made a considerable difference in terms of energy savings. The savings in the heating load were higher than in the cooling loads in all cases. When the infiltration rate was 3 ach, the heating savings were 11.9% and 6.8% for cooling. When the infiltration rate was 2.7 ach, the heating savings increased to 28.3% for heating and 14.6% for cooling. When increasing the airtightness to 2.0 ach, the heating energy savings approached 40.0%: 22.0% for the heating and cooling energy.

- The effect of combined interventions

In this phase, the optimized measure in each of the previous elements were examined. After running the simulation using the configurations in the energy used for heating was 650.0kWh, and for cooling 149.0 kWh. The energy savings are calculated based on the use of (HVAC) system for certain hours during the heating and cooling seasons. The heating and cooling energy savings are 4448.0 and 183.0 kWh respectively. This is equivalent to savings of 79.0% for heating and 55.0% for cooling. A summary of the effect on heating and cooling and overall savings is given in Figure 6. When applying the combined intervention CINV while using the air conditioning for heating and cooling in the manner described earlier.

Conclusion

Using energy in a rational way is important especially for the developing countries. It becomes more important in countries witnessing conflicts. Optimizing the energy used in building is crusial to use the energy effeciantly. In certain context, several energy sources are used which make it hard to model through the conventional methods (using energy bills). (DES) modelling is useful, however, these models should be built to recflect the actual consumption through considering the users behaviour. Moreover, they need to be validated before introducing any energy conservation measures. In this paper, a case study apartment was modeled in the city of Hebron, Palestine. The model integrtaed the behaviour of the users then was validated depending on the internal temperature.

The optimization shows that using external insulation of 8 cm the extruded polystyrene covered with natural stone cladding can save up to 12.5% of the heating energy and 2.7% of the cooling energy. Using extruded polystrnen that is covered by plaster in the ceiling can save up to 0.8% of the heating energy while the cooling energy savings was 2.2%, with a total saving of 0.7%. When applying CC3, heating saving increased slightly to 0.8%, while the cooling energy savings were 2.2%. Insulating the internal walls can save up to can save 7.3% of heating energy and 1.8% of cooling energy, while the total energy saved using insulated external doors was 2.2.%. Using tripple glazing can save 1.55 of the heating and 0.4% of the cooling energy. Decreasing the infiltration rate was crucial in decresing the energy consumption. Decreasing the infiltration rate to 2.7 ach can save 28.3% of the heating and 14.6% of the cooling energy. This shows that the proiority in retrofitting is decreasing the infiltration rate and using insulation in the external walls. Using the combind interventions can save up to 79.0% for heating and 55.0% for cooling. This shows that these measures can save a huge amount of energy if was applied on the existing stock and was considered while constructing new buildings in Palestine.

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