Energy Performance Benchmarking Methodology for Palestinian School Buildings in Gaza strip

Nagham Kh. Ali-Hasan[1], Prof. Ahmed R. Abdin[2], and Dr. Khaled M.F. El-Deeb[3]

[1] Department of Architecture, Faculty of Engineering, Cairo University

[2]Prof. Of Architectural Design, Department of Architecture, Faculty of Engineering, Cairo University.

[3]Lecturer, Department of Architecture, Faculty of Fine Arts, Alexandria University

Corresponding Author: Nagham Kh. Ali-Hasan. Email: Ahasan136@gmail.com Tel: 002 012797852148

ABSTRACT:

In Palestine, nine hundred classrooms are needed to be built every year to cope with the increase in population. Many schools were obligated to work on the double shift basis to solve the problem. The Ministry of Education (MOE), the United Nations Relief and Works Agency for Palestine Refugees (UNRWA), and Private Sector are the three entities that provide educational facilities in Palestine. In most cases, the school building designs are standard prototypes that are not site-specific or climate-based. This resulted in thermal discomfort in educational spaces that lead many schools to install HVAC systems to maintain indoor comfort.

School building designs are required to be more efficient climate-based and energy-conscious while maintaining indoor comfort levels. Despite the presence of a Palestinian energy-efficiency building code since 2004, no energy benchmarks for buildings were specified. In order to develop energy-efficient school building designs in Gaza strip, an energy benchmark is needed to assess new designs. This study aims to develop an energy building dataset methodology in order to benchmark energy performance of Palestinian school buildings at an early stage of the design.

The benchmarking methodology was based on field survey and simulation methods. Based on the survey, two school buildings representative of schools developed by MOE and UNRWA were selected and were used as reference buildings. Both were simulated for energy performance, delivering energy use intensity (EUI) for heating, cooling, and lighting. A virtual building database was created to test alternatives of building envelope parameters, classroom occupancy density and building orientation. An optimized best practice building was developed. Its EUI value was used as target values. The savings compared to reference buildings of MOE and UNRWA reached 28% and 35% respectively.

***Keywords**: Energy Performance, Building Envelope, School Buildings, Benchmark*

منهجية تحديد مؤشر أداء الطاقة بالمباني المدرسية في قطاع غزة بفلسطين

الملخص:

تهدف هذه الدراسة إلى وضع منهجية لبناء قاعدة بيانات خاصة بتقييم أداء الطاقة للمباني المدرسية المكيفة في قطاع غزة في مرحلة التصميم. يتولى الاشراف على التعليم في مناطق السلطة ثلاث مؤسسات تعليمية هي وزارة التربية والتعليم والاونروا والقطاع الخاص
تحتاج المناطق الفلسطينية إلى توفير ٩٠٠ فصل دراسي سنوياً نتيجة التزايد المستمر في أعداد الطلبة، مما نتج عنه زيادة عدد الطلبة داخل الفصل الدراسي. وقد قامت وزارة التربية والتعليم بوضع استراتيجيات لتحقيق الاستدامة لتحقيق الراحة داخل الفراغات التعليمية، ولكن ما زالت تعاني هذه المباني من عدم تحقيق الراحة الحرارية داخلها في الفترات التعليمية التي يقضي بها الطالب أطول فترة، مع تزايد الطلب على نظم التكييف الميكانيكية مع التأكيد على الحاجة الماسة لتقليل الطلب على الطاقة.

يمثل جمع البيانات عن المباني المدرسية المكيفة في فلسطين مشكلة كبيرة حيث لا توجد بيانات كافية عن كمية الاستهلاك أو مرجعيات يمكن الاسترشاد من خلالها. لذا كانت الحاجة لتكوين قاعدة بيانات أو قيم مرجعية لتحديد مؤشر لأداء الطاقة في المباني المدرسية في فلسطين، وقد حددت الدراسة عناصر غلاف المبنى كأحد أهم عوامل قياس الطاقة وذلك بالاستعانة بأسلوب المحاكاة والدراسة الميدانية في جمع المعلومات والبيانات عن المباني المدرسية في غزة.

قامت الدراسة بدايةً باستعراض الحالة الراهنة للمباني المدرسية في فلسطين والجهود المبذولة للتصميم المستدام ونظم تقييم الطاقة وذلك لبلورة الأفكار حول كيفية تحسين الأداء، من ثم طورت الدراسة نموذج محاكاة افتراضي يحدد خصائص غلاف المبنى إضافة إلى المتغيرات المختلفة لإشغال المبنى والتوجيه، وتستند عملية القياس في هذه الدراسة على البيانات الفعلية والمعلومات التفصيلية للمباني من خلال الدراسة الحقلية. وقد توصلت الدراسة إلى وجود نموذجين محددين للمباني أحدهما تابع لوزارة التربية والتعلية **MOE** بقيمة استهلاك ١٩١ك.و/م٢ وآخر تابع **UNRWA** بقيمة ٢١١ ك.و/م٢. هذا ويمكن إجراء تحسينات على أداء غلاف المبنى للوصول إلى أقل معدل استهلاك للطاقة، من خلال تقنين أداء الطاقة تم التوصل إلى أفضل أداء للطاقة بقيمة ١٣٧ ك.و/م٢.

INTRODUCTION

There are three types of authorities providing education to the Palestinian students: the government – through the ministry of education (MOE), the United Nations Relief and Works Agency for Palestine Refugees (UNRWA), and Private Sector [1]. Palestinian school buildings (PSB) in Gaza followed two standard designs applied by MOE and UNRWA. Using standard designs minimized the construction period and minimized cost [2]. However, in terms of sustainability and energy-efficiency, the performance of these prototype designs becomes questionable. Although strategies have been developed to achieve thermal comfort in the educational spaces such as classrooms, these buildings still suffer from thermal discomfort at periods of learning. The growing demand for air-conditioning systems that help achieve comfort levels creates a challenge against the urgent need to reduce energy consumption in school buildings.

In order to investigate the potential of achieving energy-efficient school buildings adapted for the climate of Gaza strip, there is a need for reference building values to be used as a benchmark for comparison. In Palestine, there are no sufficient database or target values for energy consumption that can be used as an index for energy performance. [3]

This study aimed at developing a benchmark of energy performance of air-conditioned school buildings located in Gaza strip. The energy-saving potential can be estimated by comparing the energy performance indicator(s) (EPI) or energy use intensity (EUI) of a specific building with reference and target values of a building with the same function or with a best-practice building [4].

Filippin (2000), calculated the EUI for school buildings in central Argentina. The energy efficiency and emissions of greenhouse gases for 15 public school buildings were compared [5].

Hernandez et al. (**2008)** developed detailed questionnaires that were distributed to 350 schools in Ireland in order to collect detail on building construction, activities and energy uses in each building. The comparison benchmarks for the annual energy use heating were for reference buildings stock and reference regulation buildings that have been proposed by The European Committee for Standardization (CEN) [6].

Nikolau, T. G. (2010) developed a dynamic simulation model for generalization and creation of virtual building dataset (VBD) of random office buildings located in different climatic zones in Greece, taking into account the constructional and operational characteristics of the buildings and Greek legislation. The simulation outputs were EUI values of the annual energy demand for heating, cooling, electric lighting and office equipment in addition to indoor thermal comfort [4].

Radhi et al. (2008) developed a database and benchmarking software based on on-site surveys and detailed audit information. The database represented an archive for energy use in buildings and provided a comparative model. The considered operational variables included climate, building type, floor area, occupancy and equipment. The software performed two functions: assessment of energy-efficiency of buildings compared to similar buildings nationwide; and setting a realistic and achievable energy target of a medium sized office building in Bahrain that was benchmarked using a database and benchmarking software and compared the outcome with that from a recent benchmarking field study [7].

The most common method for creating a database is through the collection of building data in audits. Despite this, the creation of representative building data sets based on the application of building simulations for a range of energy parameters (virtual data set) could constitute a reliable and time-saving substitute for the real building data collection [4].

Literature showed that in addition to building energy audits, using energy performance simulation tools is beneficial in the benchmarking process to help model and assess new and existing buildings using alternatives of construction materials and building parameters, in order to specify target reference values.

This study aims at developing a suitable methodology that helps provide a benchmark for energy performance of an air-conditioned school building located in the Gaza strip.

1 LIMITATIONS

This research is limited to the parameters of external walls of the building envelope, classroom occupancy density and building orientation.

2 RESEARCH METHODOLOGY:

The benchmarking methodology as illustrated at figure (1), was based on field survey and simulation methods. Based on the survey, two school buildings representative of schools developed by MOE and UNRWA were selected and were used as reference buildings. Both were simulated for energy performance, delivering energy use intensity (EUI) for heating, cooling, and lighting. A virtual building database was created to test alternatives of building envelope parameters, classroom occupancy density and building orientation.

The methodology adopted in the study for collecting data and setting the database can be summarized in the following steps:

1. In order to figure out the current situation of Palestinian school buildings (PSB) in terms of performance, a literature review of the educational system, building design and local energy code was conducted, and the local climate was analyzed.

2. An on-site survey of school buildings located in Gaza was performed to detect the commonly used construction materials. A detailed survey template was designed for a number of local existing school buildings in Gaza. The surveyed

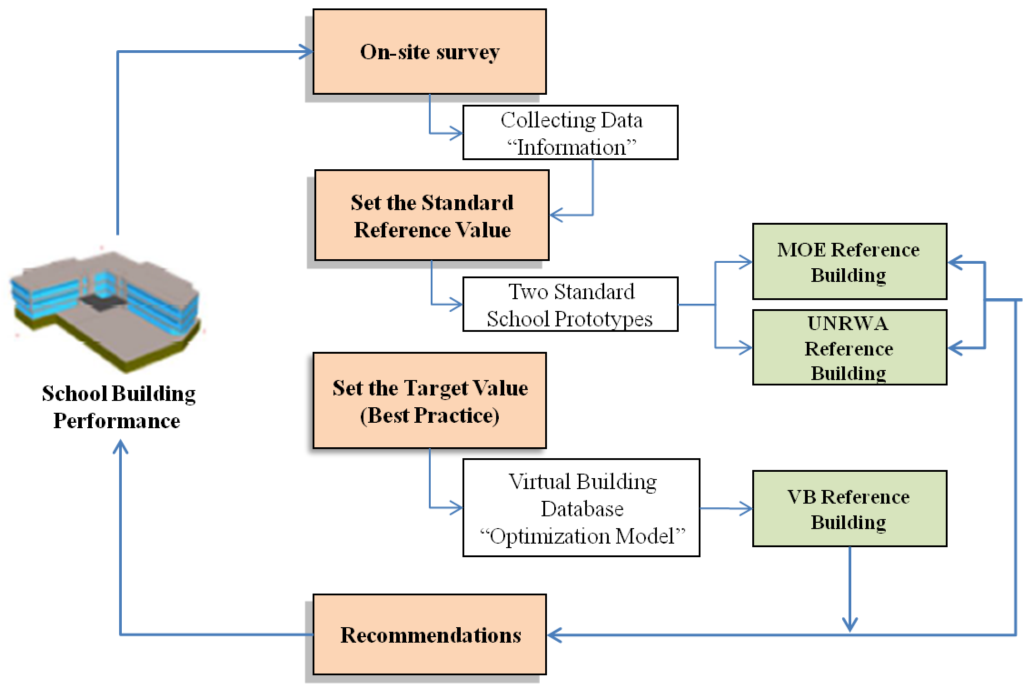
school buildings included the school prototypes developed by both of the MOE authority and UNRWA.

3. The school prototypes developed by both MOE and UNRWA were modeled in *Designbuilder* software. The commonly used construction materials deduced from the on-site survey were implemented in the models. Both models were simulated for annual energy performance using the *EnegyPlus* software as the simulation engine. The resulting annual EUI values for both prototypes were set as reference values of the existing school buildings and were used for comparison.

4. As the building envelope is a key contributor in a building's energy performance, a third virtual model was developed and used as a Virtual Building Database (VBD) in which alternatives of building envelope parameters were tested for their impact on the overall annual EUI. The tested parameters included the construction materials of opaque and transparent parts of the envelope as well as alternatives of the window-to-wall ratios.

5. Based on the results of testing alternatives of each component of the building envelope, an optimized model was developed using selected alternatives that proved to minimize the consumed energy. The EUI results of the optimized model showed a best practice building. These values were compared to the EUI values of the two reference buildings developed by the MOE and UNRWA in order to investigate the potential energy savings.

Figure (1) The research methodology steps framework



3 Background of Palestinian schools (PSB):

The West Bank and Gaza Strip -usually called the Palestinian Territories (PT)- are located at latitude 31°N. Gaza Strip region (365km^2) which is a coastal area in the west-southern part of Palestine at geographical coordinates (31°N, 34°E). It forms a transitional zone between the sub-humid coastal zone of Palestine in the north, the semiarid plains of the northern Negev Desert in the east and the arid Sinai Desert of Egypt in the south [8].

3.1. Energy situation:

The residential and commercial sectors in the PT account for about 60% of its electricity consumption, most of which is used for heating, cooling and lighting in buildings. The PT remained largely dependent on energy imports from Israel [9].

There are three providers of electric energy that supply Gaza with electricity. The first is the Israeli electricity company, which supplies 120 MW. The second is the power station of Gaza and its theoretical capacity is to produce 140 MW, however, it usually produces one third of this capacity. The third one is the Egyptian electricity grid that supplies Rafah city in Gaza Strip with around 27 MW. However, the supplied electricity does not fulfill the demand. This results in frequent power outages and in the need to use fuel generators for the most essential facilities [10].

Figure (2) Map of Palestinian Territories and Gaza Strip

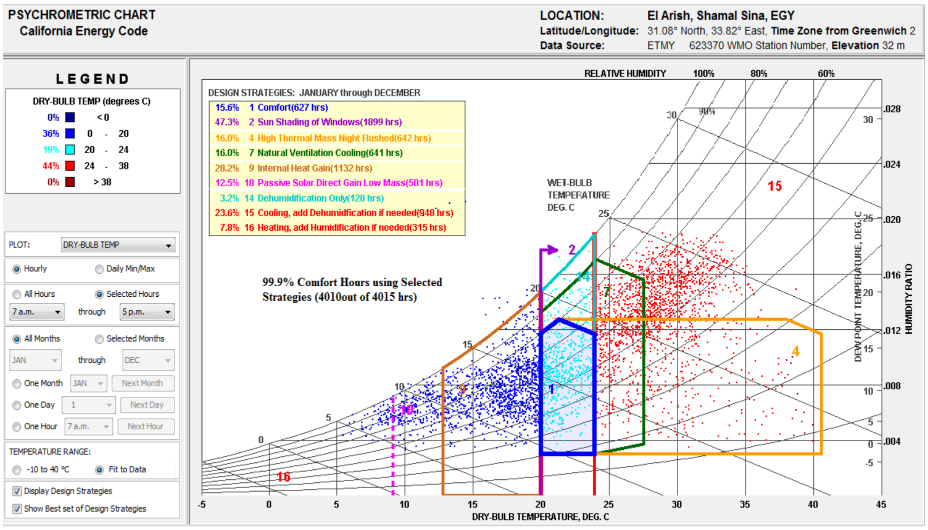
Source: http://en.wikipedia.org/wiki/Gaza_Strip

3.2. Climate analysis:

The average mean temperature for Gaza ranges from 25^{0}C in summer to 13^{0}C in winter. Daily relative humidity fluctuates between 65% in the daytime and 85% at night in the summer, and between 60 % and 80 % in winter [8]. It has a relatively high solar radiation approximately 2861 annual sunshine -hour sunshine throughout the year with average daily solar radiation on a horizontal surface is about 222W/m^2 [9].

There was no available weather data file for Gaza sector. This study used the weather data of the nearest city which was Al-Arish city in Egypt. The psychometric chart during the schools' occupancy period (from 7:00 am to 5:00 pm), (Figure 2), showed that the period that lie out of comfort zone was 80% annually. The temperature was higher than the comfort zone in 44% the occupied period while it was lower than the comfort levels in 36%. This indicated that the building envelope design and composition should be thoroughly considered to mitigate the effect of external climatic conditions.

Figure (3) Psychometric chart of Al-Arish weather data



Source: [18]

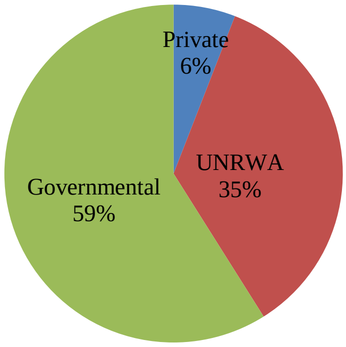
3.3. School Buildings in Palestine:

Palestine has a high natural growth rate with an annual increase of about 4.5% [11]. Because of that, the Palestinian government continued to increase the number of schools by building about 900 new classrooms every year in order to cope with this annual natural increase [12].

3.3.1. Structure of Educational System:

The total number of schools in 2012/2013 was 2,753. Of them, 74% were located in the West Bank and 26 % in the Gaza Strip. In Gaza Strip, more than 460,000 children attend 688 elementary and secondary schools. Of them, 396 schools were developed by the government (59%), 244 by UNRWA (35%) and 48 ones by the private sector (6%). These schools were designed according to the standards manual developed in cooperation with UNESCO [1]. The traditional “standard school designs” were (“I”, “L”, “A” or “U” shaped buildings that were not site-specific) [14].

Figure (4) Structure of the Educational System of PSB at Gaza



Source: Palestinian Central Bureau of Statistics, March 2014.

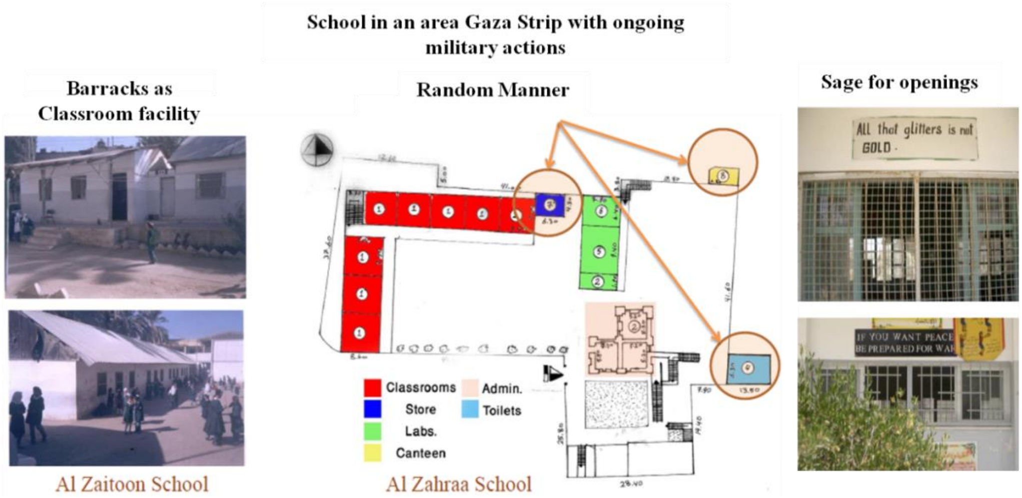
Double shifts and class occupancy density: Due to the increasing number of students, many schools have been forced to operate on double and triple shifts, leading to reduced learning time. It is estimated that an additional 260 schools (160 schools for the MOE and 100 for UNRWA) are needed to accommodate new students and to reduce the pressure on schools operating on a double and triple shifts [15]. The overall number of schools operating on a double shift system was reduced from 86% in 2012 to 71% in 2013 and the class occupancy density was maintained at 38 students per classroom, down from 49 students per classroom in 2000, in spite of the population increase [17]. The occupancy density in elementary schools was higher in Gaza (42 students per classroom) than in the West Bank (31 students per classroom). The local standards specify 36 students per classroom as a recommended number [14].

3.3.2. School Building development in Palestine

The development of schools in Palestine passed through several phases:

1. **Pre 1994 Phase:** Schools were built randomly to accommodate the continuous increase in the number of students without considering the provision of basic amenities such as laboratories, playgrounds, computer labs and other facilities. Environmental considerations were, in general, not accounted [16].

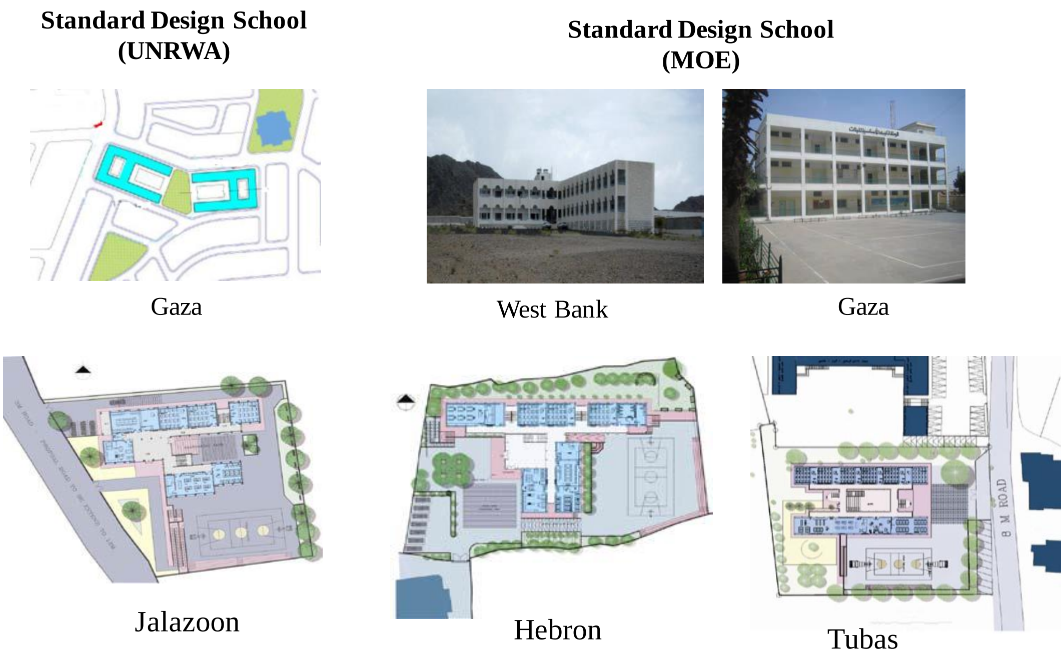
Figure (5) Random design for school facilities (Gaza)



Source: [16]

2. **Phase of the Palestinian Authority**: the authority moved towards supporting institutions and associations to help provide and improve education for Palestinian students. That created many of the school buildings funded by donors such as KfW (German government-owned development bank), EIB (European Investment Bank) and USAID (U.S. Agency for International Development). Such donors helped the MOE launch projects that showed changes and development in school design to consider the surrounding environment (colors, materials, landscaping etc.) [2]. School designs and construction drawings were provided from the donor's side.

Figure (6) Examples ofschooll building at different citiesint Palestine



Source: [2] and [14]

3. **Since 2008,** MOE and UNRWA have been engaged in the implementation of pilot projects to create environmentally friendly school facilities “eco-schools”, with the aim of reducing the burden on the environment, contributing to environmental education, promoting for the development of this type of schools. As a result of these efforts, Palestine, now is trying to design and build numerous eco-school model projects [12].

The need for new schools, extensions and rehabilitations in the West Bank and Gaza is still immense. Although many schools started to make a decisive move towards sustainable development, the existing schools in Palestine need to be more sustainable. There is little indication that these efforts have succeeded in changing overall design practices in Palestine towards improved energy efficiency.

4 Local School building’s Energy performance:

For almost 30 years, countries as the UK have been producing energy benchmarks and performance guides. For example, the Good Practice Guide 343 considered that typical and best practice values for primary schools are **157**kWh/m^2/year and **110**kWh/m^2/year respectively. In the code of practice on Energy Efficiency and Use of Renewable Energy for Non-residential Buildings, it is suggested that the target EUI for office buildings is **the 136kWh / year**/m^2 [6]. In Palestine, there is still a need to establish benchmarks to enable comparison of a particular building’s energy performance.

4.1. The Energy Efficient Building Code for Palestine:

In 2004, the project of the development of an Energy Efficiency Building Code (EEBC) for PT was completed. It focused on the climate of Palestine region for West Bank and Gaza [17]

The goal of this code was to promote energy conservation in buildings via the appropriate thermal design of envelope building elements, and to promote environment protection by reducing the greenhouse gas emissions from heating and cooling of buildings. It was expected to guarantee thermal comfort and healthy indoor environment, which would increase productivity [3].

The code contents included basic principles of thermal design, thermal storage and its role in construction elements, and the use of thermal insulation. It included thermal properties of construction materials [17]. It did not specify energy benchmarks for any building type. The code is not mandatory and not extensively adopted. This study used the code as guidance for material thermal properties.

4.2. Setting Benchmark for Palestinian Schools Application:

The process of setting the benchmark included the on-site survey, modeling and simulation of two reference buildings in addition to modeling and simulation of the virtual building database.

4.2.1. On-site survey:

The process of data collection was applied through on-site questionnaires and surveys from building facility managers and school design drawings of 10 schools in Gaza strip. The selection of schools was based on both their size and date of construction. Average-sized schools that included 28 to 33 classrooms were selected. Schools constructed date starting from the 2000 was eligible for selection to represent the second phase of school development in PT.
The collected information for school buildings included:

- Building envelope description
- Operational data: HVAC system, school schedule and occupancy density.
- Annual energy consumption of electricity recorded from the energy bill.

Table 1 shows the survey results of existing building characteristics. In local school buildings, the hollow cement block was commonly used for walls. Single glazed windows were the common case, School occupancy densities were high. It ranged from 40 students per classroom for low-basic level schools and 36 for high-basic level. This high density forced the school schedule to be worked on a double shift basis. The main energy use was consumed by artificial lighting as HVAC uses for laboratory spaces only. The surveyed schools included prototypes developed by both MOE and UNRWA.

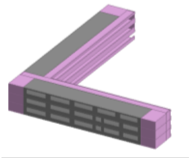
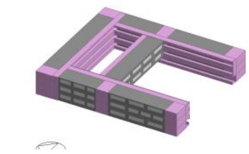
Table (1) Existing building characteristic

Element	U- value (W/m^2-K)
Roof	1.93
External Wall	1.23
Floor	2.1
Glazing type	5.7
Schedule	Double shift From7:00am-4:45pm
Activity	Basic learning school

4.2.2.The Standard Reference Building:

The MOE and UNRWA school building prototypes were modeled and simulated for energy performance using the common construction materials were derived from the survey. Table 2 shows the tested schools' design and simulation parameters. Annual and monthly energy consumption for heating, cooling and artificial lighting was the derivatives. For the current growing need to condition, educational spaces, both school buildings were assumed to be air-conditioned.

Table (2) Input data of existing reference building

Building construction material:				School A: MOE	School B: UNRWA
U-value ($W/m^2.K$)	**External Walls**	2.74	20cm Single hollow block cement	Total area = 1720 m^2 Occupancy= 0.625student/m^2 	Total area = 1245.5m^2 Occupancy = 0.75 student/m^2 
	Glazing	5.7	Single glazed 6mm: **VLT:** 0.88%, **U-value:** 6.12 W/m2.K**, SHGC:** 0.81		
	Roof	0.642	Hollow block reinforced concrete slab Insulated with 7cm concrete foam covered with single ply plastic bitumen 4mm		
Internal Lighting gain: (W/m^2) = 4.5					

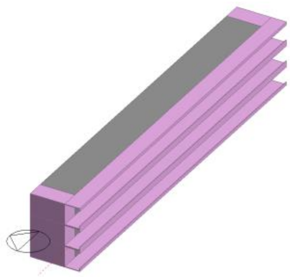
Simulation results showed that the total EUI_{MOE} = **191** kWh/m², of which 96% were used for cooling and only 4% for lighting, while heating energy consumption was negligible. On the other hand, the EUI_{UNRWA}= **211**kWh/m² of which 93% for cooling and 7% for lighting. It was clear through monthly results that energy for cooling increased in the period from April to October. It was observed that internal heat gain from occupancy was larger than heat gains from external loads by about 9%. This result indicated that the occupancy is a main parameter that had to be considered.

4.2.3.Virtual Building Database and Best-Practice:

Virtual Building Database (VBD) was developed in order to assess the effect of alternatives of building envelope components and occupancy alternatives on energy performance. On this model different envelope parameter were investigated by testing the different alternatives of building envelope components, Table 3. This included external wall U-value, thermal insulation thickness, window-to-wall ratio (WWR) and the type of glazing. Different classroom occupancy densities were also investigated. The building model was tested in the four cardinal orientations. Internal loads from occupancy and artificial lighting only were accounted for.

First, alternatives of each single parameter were tested, and then based on the results; the optimum performing alternatives of all tested parameters were combined, applied on the model and simulated. This represented the suggested optimized best practice case. The detailed results of the whole experiment including all tested parameters are discussed in a separate research. The results of the best practice case are shown in this research**.**

Figure (7) The base case design for Virtual Reference Building



Area : 304.7 m^2
WWR: 25%
Flat roof 0.52 $W/m^2.K$
External walls 2.70 $W/m^2.K$
Windows 6.12 $W/m^2.K$
Lighting 300 Lux
Occupancy 0.8 students/m2
Split & mech. Ventilation

The base case model

Table (3) investigated variables for the base case

<table>
<tr><th>Parameter</th><th colspan="4">Range of values</th></tr>
<tr><td>Building orientation</td><td colspan="4">N, E, S, and W</td></tr>
<tr><td>Occupancy</td><td colspan="4">0, 0.4, 0.6, 0.8, 1.0, and 1.2 student/m2.</td></tr>
<tr><td rowspan="5">External walls</td><td colspan="3"><u>Wall type</u></td><td><u>U-value</u></td></tr>
<tr><td colspan="3">Hollow cement block,</td><td>0.77</td></tr>
<tr><td colspan="3">Solid Concrete block,</td><td>1.67</td></tr>
<tr><td colspan="3">Hollow cement block with an outer limestone layer 5cm,</td><td>2.18</td></tr>
<tr><td colspan="3">Cavity wall with an outer limestone layer 5cm</td><td>1.7</td></tr>
<tr><td>Insulation</td><td colspan="4">Hollow cement block with 3,5,7 cm of insulation layer</td></tr>
<tr><td>Window-to-wall ratios “WWR”</td><td colspan="4">15%, 20%, 25%, 30% and 35%, the ratio of glazed area to both inside and outside facing wall.</td></tr>
<tr><td rowspan="7">Glazing type</td><td>Glazing type</td><td>Visible light (VL) Trans.</td><td>SHGC</td><td>U-value</td></tr>
<tr><td>Single clear 6mm</td><td>0.88</td><td>0.81</td><td>6.12</td></tr>
<tr><td>Single green 6mm</td><td>0.75</td><td>0.59</td><td>5.70</td></tr>
<tr><td>Double green (6mm-13mm air space)</td><td>0.66</td><td>0.49</td><td>2.71</td></tr>
<tr><td>Double clear LoE e2=1 (6mm-6mm air space)</td><td>0.75</td><td>0.56</td><td>2.44</td></tr>
<tr><td>Double clear LoE e2=1 (6mm-13mm air space)</td><td>0.75</td><td>0.56</td><td>1.78</td></tr>
<tr><td>Double clear LoE e2=1 (6mm-13mm argon)</td><td>0.74</td><td>0.56</td><td>1.50</td></tr>
</table>

The optimized best practice model parameters included external walls of hollow cement block (U-value 0.77), no thermal insulation, window-to-wall ratio 25%, double glazed green tinted glass in windows and occupancy of 30 student/classroom (0.6 student/$m^{2)}$.

The simulation results of the best practice school building are presented in figure (7). Results showed that the south-oriented building was the highest in consumption, followed by the east and west-oriented classrooms. The north-oriented classroom case was the lowest in consumption that reached a total EUI of only 137kwhr/m^2. This value represents the achievement of 28.2% savings when compared to the MOE reference school building and 35% savings when compared the UNRWA reference school building.

Despite being the highest in energy consumption, the south-oriented case achieved significant savings reaching about 10% and 18% when compared to the EUI of the MOE and UNRWA reference buildings respectively.

These results indicated that large energy savings were achieved by making an optimized combination of construction materials and design of the building envelope joint with adjusted occupancy density and appropriate orientation.

Figure (8) total energy use for the three reference values for school building located in Gaza, Palestine
"MOE reference building, UNRWA reference building and Virtual reference building"

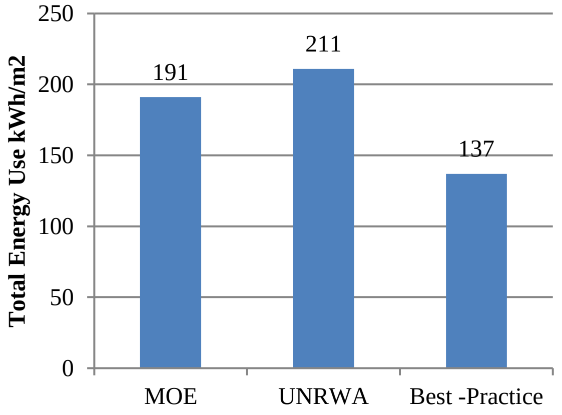
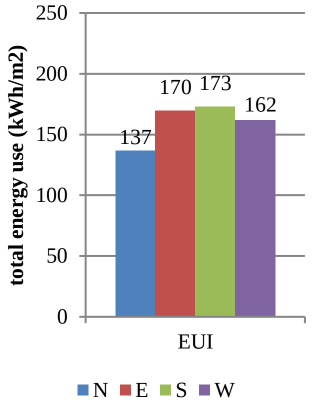


Figure (9) –the base case annual heating, cooling and lighting Loads, at WWR 25% and 0.6 occupancy



5 CONCLUSION

There is an increased demand on air-conditioning Palestinian school buildings in order to maintain comfort. In the meantime, there is a lack of energy resources and an increased demand for energy-efficiency in school building design. The energy School building envelope characteristics determine a large part of energy used in a school building

The two main studied prototypes represented the most common standard applied cases for school buildings developed by both MOE and UNRWA. Both prototypes were considered as standard reference buildings, modeled and simulated for energy performance using the common construction materials. Annual EUI values for MOE and UNRWA prototypes were 191 and 211KWh/m^2 respectively, and they were considered as standard reference values. They were far higher than international target values. The energy performance of the simulated buildings was, thus, not efficient. Internal loads from occupancy were 9% more than external loads from the envelope and indicated that specifying occupancy density is crucial.
VBD can help the designer figure out, at the early design stages, what the most energy-efficient alternatives of building envelope design and construction materials are by offering an experimental platform that enables quantitative comparison between alternatives of building parameters. A VBD was modeled and used to make an extensive testing of different alternatives of building parameters under the local climate. It enabled prediction of energy performance for a large number of variables. Best values for each building component were combined in an optimized model.

Based on VBD simulation results, the recommended building parameters for school buildings in Gaza include: external walls of hollow cement block (U-value 0.77) with no thermal insulation, window to wall ratio (WWR) 25%, double glazed green tinted glass in windows and occupancy density limited to 30 student/classroom. The building should be north-oriented.

The north-oriented building optimized model resulted in annual EUI 137kWh/m^2 which was quite close to international standards. This value represents a best practice case and a target value that can be used to benchmark air-conditioned schools in the local climate of Gaza according to the tested parameters.

The methodology applied in this research can be extended to other building parameters, adapted to the other types of buildings and other climate data of other Palestinian cities.

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