Energy consumption baseline for public schools in the West Bank-Palestine

Sawsan Dmaidi, Luay N. Dwaikat [*], Muhannad Haj Hussein

Department of Building Engineering, An-Najah National University, West Bank, Nablus, Palestine

ARTICLE INFO

ABSTRACT

Schools play a significant role in social development which is one of the three major pillars of sustainable development. Schools are also a hub to promote sustainable practices, and hence, it is imperative to measure the actual energy performance of school buildings. This research was designed to quantify the actual energy consumption in public school buildings in the West Bank in Palestine to establish a baseline for energy consumption in public school buildings. Methodologically, the historical energy performance of a representative random sample consisting of 103 schools in the West Bank was statistically analysed. The results show that the average annual energy consumption in public school buildings is 10,368 kWh, while the annual energy use intensity is around 8.35 kWh/m^2/year, and 35.44 kWh/student/year. The results presented in this research are not surprisingly low due to the fact that energy consumption in school buildings is heavily determined by heating, ventilation, and air conditioning (HVAC) systems which often do not exist in public school buildings in the West Bank. This research is the first to provide empirical statistical evidence about the actual amount of energy consumed in public school buildings in the West Bank, as well as it is the first to present a baseline energy consumption for public schools. The results presented in this research can be used as an industry benchmark by policy and decision-makers to assess green schools' performance which, besides reducing the negative impacts on the environment, have the potential to improve health, productivity and, education environment.

1. Introduction

In the executive summary of the 2020 global status report for buildings and construction issued by the United Nations Environmental Program (UNEP, 2020), it is argued that the CO_2 emissions from the building sector reached unprecedented levels and, in 2019, it reached the highest level ever recorded. According to the above-mentioned report, the building sector is still the largest energy-consuming sector, it is estimated that the building operations consume around 55 % of the total global electricity consumption. Therefore, there is no debate in the scientific community that it has become imperative to reduce energy demand in buildings.

Relying on actual energy consumption data, scholars worldwide have flocked to established energy consumption baselines and benchmarks for various building types. Energy consumption baselines are essential to assess the actual energy performance of buildings and to help reaching proper design strategies for energy efficiency. de Oliveira Veloso et al. (2020) reported 127 kWh/m^2/year as the average energy consumption for office buildings in Brazil. Daly et al. (2022) reported an average of 38 kWh/m^2/year and 542 kWh/student/year for primary

schools in Australia. Katafygiotou and Serghides (2014) claim that the average energy consumption in schools in Cyprus is 65.75 kWh/m^2/year. Kim et al. (2019) reported 133 kWh/m^2/year for middle schools in Korea.

Reduced energy consumption is one of the most important incentives for adopting green buildings. Hence, it is imperative to monitor the actual energy consumption in green buildings in particular, and in non-green buildings in general (Calì et al., 2016; de Wilde, 2014; UNDP, 2015). To do so, an energy baseline is required to serve as a quantitative scale to provide a reference for measuring and comparing energy consumption and to quantify energy saving that results from energy efficiency measures (Melo et al., 2023).

The concept of green building, technically, can be applied in various building types. School buildings, for example, represent an important pillar in the socioeconomic development of a country. Schools are places where children are educated and have the opportunity to be aware of the environmental issues and the need for sustainable practices. The interest in the schools' sector is deeply motivated by the need for high levels of comfort and energy efficiency requirements. Green schools are being promoted as a response to this need, and it is vigorously argued that

---

green schools improve indoor air quality, productivity, and health (Magzamen et al., 2017).

While many developed countries have made notable strides towards achieving sustainable practice in various sectors, some developing countries, among others, Palestine, are still in early stages of meeting the sustainable development goals. Starting from the last decade, there has been a growing interest in adopting green design strategies for buildings in the Palestinian marketplace. This interest is represented in establishing several professional bodies concerned with sustainable development in the building sector, such as the Palestinian Higher Green Building Council (Palestinian Engineers Association, 2013).

The goal of adopting and applying green building design strategies in the Palestinian marketplace is to transform traditional design into sustainable practices to enhance efficient use of renewable energy sources during building construction and operating phase. In response to this need, the educational building sector, particularly schools, is the leading sector that has embraced green building design strategies. It is worth mentioning that the first certified green building in the Palestinian marketplace is a school facility, certified by the Palestinian Higher Green Building Council in 2016.

However, efforts to enhance adopting the green buildings concept for schools in Palestine can be fostered by the availability of energy consumption baselines. Energy consumption baselines are effective tools required to benchmark the actual energy performance of green schools against public non-green schools. Furthermore, energy baselines allow for quantifying the actual benefits gained from energy saving.

This research aims to establish a local baseline energy consumption for public sector school buildings in the West Bank. Establishing an energy baseline supports the efforts exerted by the Palestinian Ministry of Education to utilize renewable energy sources and to decrease energy demand in school buildings. The established energy baseline presented in this research also serves as a benchmark to be used by other scholars to evaluate the actual benefits resulted from energy saving in green schools for the Palestinian case.

2. Background information

2.1. Sustainable development

The concept of sustainable development has emerged as a response to change the traditional consumption patterns which disregard the ecological system balance. In general, sustainable development mandates achieving balance between three aspects which are: economic, social, and environmental without draining the natural resources (Kibert, 2012).

Sustainable development was proposed in 1987 by the United Nations World Commission on Environment and Development which is commonly known as Bruntland's Commission. Bruntland's Commission suggested a definition for sustainable development implies ethical responsibility towards the future generations represented in meeting our needs without depriving the future generations from meeting their own needs for natural resources and clean environment (Keeble, 1988). Intrinsically, sustainable development is a roadmap for safe growth without jeopardizing existence of humanity on this planet. This requires achieving balance between the environment, society, and economy which form the bottom line of sustainable development (Adams, 2006; Zuo and Zhao, 2014). Hence, the objectives of sustainable development focusing on raising mankind's health and welfare, stimulating equity, and natural resources sustainability.

2.2. Sustainable construction and green buildings

A green building is the product of a sustainable construction process. The terms "sustainable construction" and "green buildings" are aligned with the concept of sustainable development (Kibert, 2016). There are several principles of sustainable construction that should be adhered to

during the life cycle of a construction project represented in: less natural resources consumption, eliminating toxics, using recyclable resources, nature and ecosystems protection, focusing on quality, and applying life-cycle thinking.

The direct application of the principles of sustainable construction in producing structures that reduce the burden on the environment is referred to as green building design. Green design evolves around using technical knowledge in designing and creating structures in compliance to environmental requirements that mainly focus on using renewable energy sources, minimizing pollution, and using recyclable material. Generally, the green building is commonly described as a healthy facility that demands minimum resources for construction and operation, and that allows material recycling by the end of its life cycle (Kibert, 2012; Yudelson, 2008).

The evaluation of green design effects on humans' performance and health fosters the development of green schools as a healthy environment for learning associated with less natural resources demand. Green school buildings have positive impact on students' productivity and their physical and psychosocial health (Evans, 2003; Magzamen et al., 2017; National Research Council, 2007). This is because green schools design focuses on improving indoor air quality by reducing harmful volatile organic compounds that come from various building material (Breysse et al., 2011; Free et al., 2010).

2.3. Energy consumption in buildings

Due to the rapid growth of energy use worldwide, concerns have been raised about energy resources depletion and various environmental negative impacts such as: ozone layer depletion, climate change, and global warming. According to the United Nations Environment Programme (UNEP, 2020), climate change and global warming are associated with energy consumption and greenhouse gas emissions that jeopardize the existence of human societies.

During the period from 1984 to 2004, The International Energy Agency (IEA) collected data about the energy consumption trend, the IEA reported a 49 % growth in primary energy which represents 2 % as an average annual increase. More recent data shows that, from the year 1990 to 2018, the global residential energy consumption increased by 37.81 % which yields an average annual increase of 1.35 % (International Energy Agency, 2021)

In 2020, the United Nations Environment Program (UNEP, 2020) highlighted that the CO2 emissions that were resulted from building operations and construction reached a level of 38 % of the total global emissions related to energy. In terms of electricity consumption, it is also highlighted that 55 % of the total electricity consumption is attributed to building operations during the year 2019.

In line with the need to operate and maintain existing buildings, the need to design and construct energy-efficient buildings has become a priority. Therefore, green buildings emerged to be an appealing concept to achieve this need. Notably, due to the increased recognition of sustainable development over the past years, green buildings which are constructed based on energy efficiency measures to decrease energy consumption have been preferred over conventional buildings (GhaffarianHoseini et al., 2013).

2.4. Energy consumption baseline

When assessing the energy consumption of different buildings, a reference tool known as "energy baseline" is used (John, 2015; Melo et al., 2023; Moghimi et al., 2014). According to the international standard ISO 500006:2014 (ISO, 2014), the energy baseline is defined as a quantitative scale that provides a reference to measure and compare energy performance, it is used to quantify savings incurred from energy efficiency measures. The energy baseline can be normalized taking into account several variables that affect the energy consumption in buildings. The Building area is a frequently used variable to normalize energy

consumption in buildings (Abu Bakar et al., 2015; Moghimi et al., 2014). The normalized energy consumption in buildings based on the building area is referred to as "building energy index" (Abu Bakar et al., 2015). Some scholars use the term "energy use intensity" to describe the normalized energy consumption in buildings (Alajmi et al., 2016; Melo et al., 2023).

In the light of the previous discussion, comparing buildings' energy performance with predefined energy performance baselines is a common methodology adopted in evaluating the actual energy demand in green buildings. Energy baselines also allow for quantifying the energy saving associated with energy efficiency measures.

Promoting the concept of green buildings needs to be supported by the tools that facilitate providing empirical evidence about out-performance. As discussed earlier in Section 2.3 above, the concept of green buildings is appealing. Several benefits had been identified by a diligent and extensive body of literature. Locally, the concept in the Palestinian market is still nascent, and more efforts are still required to promote widespread adoption of green buildings. Establishing an energy consumption baseline for a popular building type, such as school buildings, is expected to support these efforts.

3. Research methodology

This research was designed to establish a reference for comparing energy consumption in public school buildings. The energy consumption baseline, which also can be referred to as "benchmark" is commonly established through simple descriptive statistics (Chung, 2011; Ouf and Issa, 2017). Chung (2011) conducted a review to investigate the mathematical methods that are used in developing energy baselines; he concludes that the descriptive statistics method is commonly used in the literature. Chung (2011) also reports that the descriptive statistics method is based on normalizing the energy consumption based on the building area. Abu Bakar et al. (2015) and Moghimi et al. (2014) also suggest using the building area to normalize the energy consumption. For this purpose, statistical data from a random sample that statistically represents the public schools in the West Bank was collected in order to generalize the findings.

3.1. Population and sampling

According to the Ministry of Education, there is a total of 1825 schools under service in the West Bank located in 17 cities as shown in Table 1 below. These schools represent the population for sampling.

To generalize the findings, a statistically representative sample is required. However, the size of the required sample is debated (Weiss, 2012). In other words, the appropriate sample size in statistical studies is among the frequently posed questions. In the literature, there is a consensus among scholars that the sample size has to be large enough to generalize the findings and there are several ways to determine the size of a random sample (Bartlett et al., 2001; Naing et al., 2006; Weiss, 2012). In the research, Thompson formula was adopted to determine the

sample size, see Eq. (1) (Thompson, 2012)).

$$n = \frac{NP(1-P)}{\left((N-1)\left(d^2/z^2\right)\right) + P(1-P)} \tag{1}$$

Where:

(n): sample size.
(N): population size (1825 schools).
(d): error percentage (10 %).
(p): the estimated proportion of property offers and neutrals (0.50).
(Z): 1.96 for 95 % confidence level

Applying Eq. (1) above reveals that 91 schools are the needed sample size to represent the population with a 10 % error.

Cluster sampling (two-stage sampling) approach was followed to randomly select 91 schools. The rationale behind using cluster sampling approach is that it allows for a random selection from geographically scattered population (Weiss, 2012).

Since the population is scattered in 17 cities, the cities represent the clusters for sampling. As shown in Table 1 above, the number of schools is known in each cluster. Accordingly, cluster sampling was applied as follow:

Stage 1: The random number generator available in Microsoft Excel Professional, version 2016, was used to randomly select clusters. Nablus and Ramallah as clusters were selected by the random number generator. These two cities have similar climate characteristics, therefore, Jenein city as a third cluster with different climate characteristics was purposively selected to make the sample more representative.
Stage 2: Simple random sampling was applied to select schools from each randomly selected cluster (city) in the previous step. The number of schools which were selected from the clusters is determined proportional to total number of schools in the cluster. Accordingly, at least 31 schools should be selected from Nablus cluster, 27 from Jenein cluster, and 34 from Ramallah cluster.

Based on data availability, higher number of schools was selected from each cluster as follow: 37 school from Nablus cluster, 28 from Jenein cluster, and 38 from Ramallah cluster. This yields a total sample size of 103 schools which is greater than the targeted sample size of 91 schools is discussed earlier.

3.2. Data collection

For the development of baseline energy consumption, different types of data such as: monthly energy consumption, school area, location, number of students, and school classification in terms of gender were obtained from the Ministry of Education, Municipalities, and Utility Suppliers (see Table 2 in the appendix).

The collected data of the sample include monthly energy consumption for the period from 2014 to 2018 for each school. The collected data is presented in Table 2 in the appendix.

4. Data analysis approach

As discussed in the preceding section, the energy consumption data points are actual monthly consumption for a period of five years. Accordingly, the monthly data was aggregated to annual values. The rationale behind aggregating the monthly data to annual data is that annual data exhibits less variation than the monthly data. In summer and winter school breaks and holidays, most schools are not occupied which results in low monthly readings for energy consumption. Furthermore, annual data eliminates potential monthly recording errors.

Table 1
Public schools' population in the West Bank.

No.	City	Number of schools	No.	City	Number of schools
1	Ramallah	196	10	Bethlehem	133
2	Nablus	180	11	North Hebron	104
3	South Nablus	82	12	Qabatya	91
4	Hebron	153	13	Jerusalem	51
5	South Hebron	164	14	Jerusalem suburbs	74
6	Qalqelya	80	15	Tobas	45
7	Jenein	154	16	Jericho	22
8	Yata	85	17	Salfiet	73
9	Tulkarem	138			

The Five Number Analysis (Minimum, Q1, Q2, Q3, Maximum) defines the interquartile intervals which were used to identify potential outliers (Weiss, 2012). The Five Number Analysis (Minimum, Q1, Q2, Q3, Maximum) were conducted following Eqs. (2)–(4) below (Weiss, 2012):

$$Median\ position = \frac{n+1}{2} \tag{2}$$

$$Lower\ boundary = Q1 - 1.5\ IQR \tag{3}$$

$$Upper\ boundary = Q3 + 1.5\ IQR \tag{4}$$

Where:

(n): sample size.
(Q1): the first quartile.
(Q3): the third quartile
(IQR) = the interquartile range, the difference between Q1 and Q2.

The data points that fall outside the interquartile range are identified as potential outliers of annual energy consumption. However, the identified outliers were not excluded from the analysis. This decision is based on the fact that the energy consumption data are actually recorded rather than being observed data points (Weiss, 2012).

The arithmetic mean of the sample's data points is the main parameter to measure the average annual energy consumption. However, the average annual energy consumption without normalization does not allow for comparison among schools. This is because school buildings vary in term of size and students' capacity, and thus, normalizing the annual energy consumption determines the energy use intensity in reference to a common parameter. The building energy index is a commonly used metric for quantifying energy consumption in buildings. It is calculated through dividing the amount of energy consumed during a specific time period, often in years, over the gross area of a building. The basic unit of measurement of the building energy index is expressed by kWh/unit area/time (Abu Bakar et al., 2015; Moghimi et al., 2014).

Rather than using the gross area of a building, some research scholars suggest normalizing the energy consumption based on the air conditioned area (Moghimi et al., 2014). However, due to the fact that public schools in the West Bank are not air conditioned buildings, and the main energy consumption is attributed to lighting and some electrical appliances such as computers, it is decided to normalize energy consumption based on gross areas of schools.

The occupancy density in buildings impacts energy consumption. Thus, energy consumption is also normalized based on schools' capacity. The energy use intensity per student, expressed as kWh/student/year, is another alternative to be used as a baseline energy consumption to monitor energy demand in school buildings (Kim et al., 2019).

5. Results and discussion

The data analysis shows that the median annual energy consumption is 10,060.40 kWh/year, while the first and third quartiles (Q1and Q3) are 5672.60 and 12,805 kWh/year respectively. It is worth mentioning that the first quartile (Q1) is a number represents the median of the bottom 50 % of the data points, while contrarily, the third quartile (Q3) is the median of the top 50 % of the data points.

The interquartile interval (IQR), which is the difference between Q1 and Q3 is 7132.4 kWh/year, which results in lower and upper boundaries of -5026 kWh/year and 23,503.6 kWh/year respectively. The lower and upper boundaries are the threshold to identify the outliers. Data points that fall beyond these boundaries are classified as outliers (Weiss, 2012). The identified outliers are highlighted with an asterisk (*) in Table 2 in the appendix, and illustrated Fig. 1. As highlighted earlier in the previous section, it is decided not to reject the outliers due to the fact that the data points are records of measurements for energy consumption rather than being observations (Weiss, 2012).

Including the outliers, the average energy consumption of schools is 10,367.63 kWh/year. This value represents the arithmetic mean of the data points in the sample as illustrated in Fig. 2. The energy use intensity was measured for each school by finding the arithmetic mean of the building energy index measured in reference to gross area and occupancy density, the building energy index per unit area is found to be 8.35 kWh/m^2/year as illustrated in Fig. 3, while for students it is 35.44
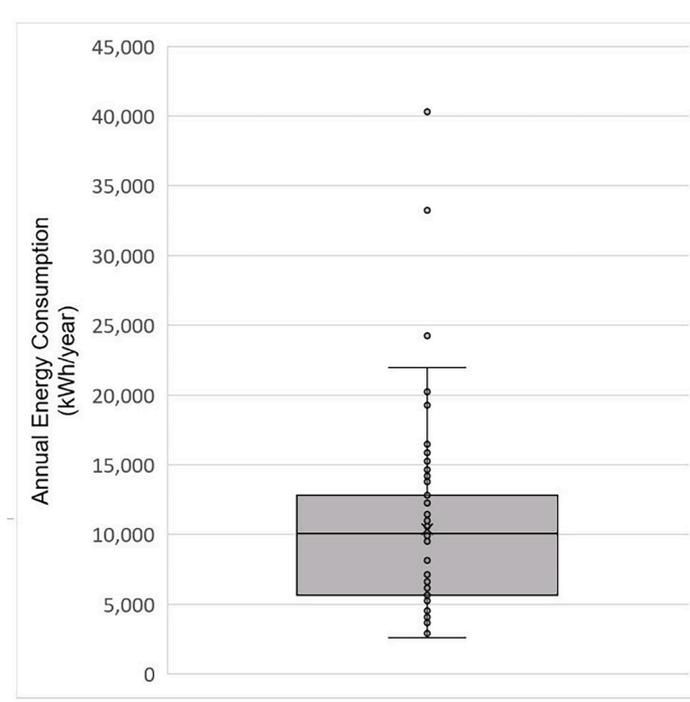

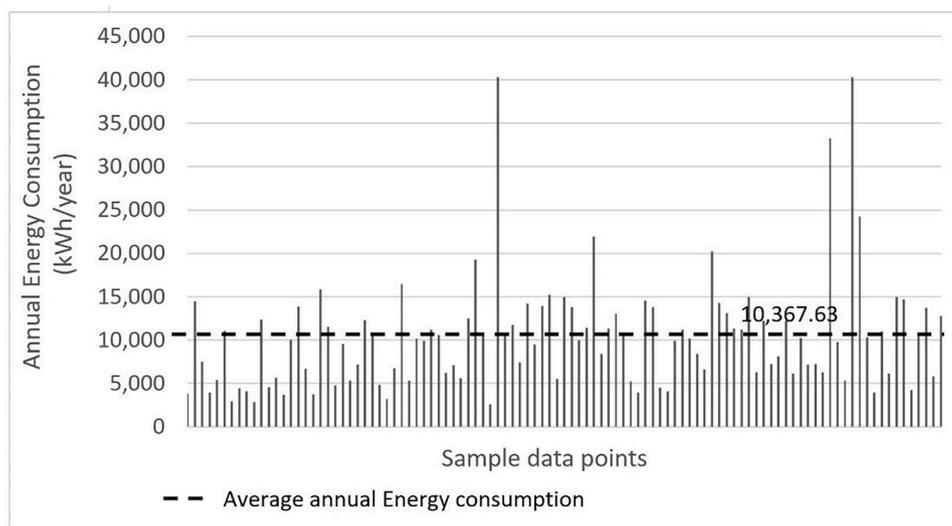**Fig. 1.** Boxplot of annual energy consumption including identified outliers.

Fig. 2. Sample's data points distribution for annual energy consumption.
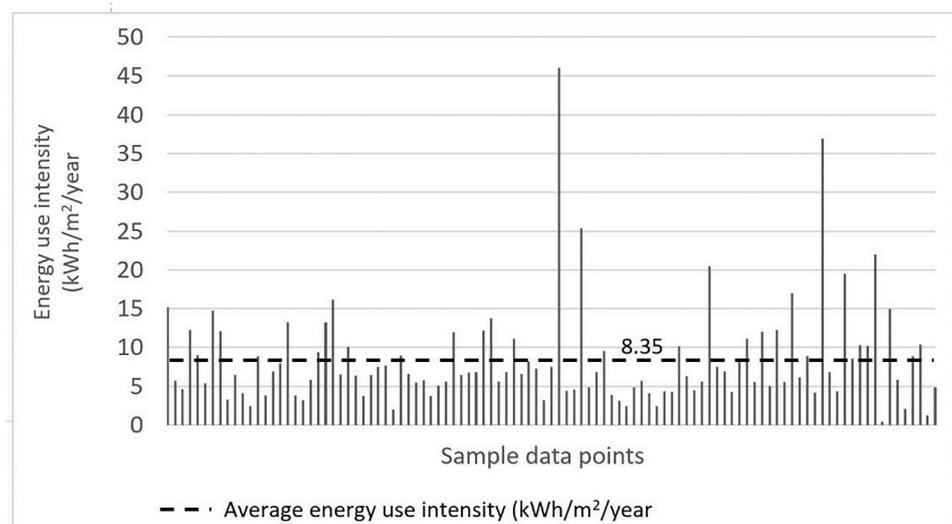

Fig. 3. Energy use intensity per unit area.

kWh/student/year as depicted in Fig. 4.

Comparing these results with findings reported by research conducted in the West Bank and other countries in the world shows that the amount of energy consumed in school buildings as found in this research is remarkably low. Hodiri (2018), in his master degree thesis, claimed 9.56 kWh/m²/year as the energy use intensity for a purposively selected sample (not randomly selected representative sample) of public schools in the West Bank. Kim et al. (2019) surveyed 9 schools in South Korea and found 133 kWh/m²/year as the normalized energy use intensity based on area, while the normalized energy use intensity based on occupancy ranging from 700 to 1800 kWh/student/year. Similar research was conducted in Ireland by Hernandez et. al (2008) in which 96 kWh/m²/year is reported as the median and 65 kWh/m²/year is reported as the upper quartile for a sample consists of 88 schools. Another range from 17 to 26 kWh/m²/year and 289–734 kWh/student/year was claimed by Wang (2016) in Taiwan.

It is evident that the reported energy use intensity in this research is far below reported average consumption in school buildings in several countries. Arguably, this relatively low energy use intensity, reported in this research, could be attributed to the fact that lighting and appliances rather than air conditioning are the key attributes of energy consumption in the public schools. Sources of energy consumption in classrooms in public school buildings are primarily limited to lighting. Classrooms are not equipped with projectors, computers, interactive whiteboards, or smart boards for educational purposes. Considering the size of these electronic devices and tools which is determined by the number of classroom in each school, these devices potentially consume significant amount of energy, especially if used for extended periods of time. Notwithstanding, limited number of computers can be found only in a computer lab, which are purposively used for educating computer skills for students. Most importantly, classrooms are neither cooled in summer nor heated in winter with power consuming cooling and heating systems. Fans for ventilation are occasionally found in some instances.

In term of energy users, limited administrative staff often exists in public schools, with limited number of appliances such as printers, faxes, and photocopy machine. Therefore, it can be argued that both students and teachers are the main users of energy in school buildings with lighting as the major source of energy consumption.

In term of building occupancy period, school buildings are only occupied during two academic semesters in a year, each of which
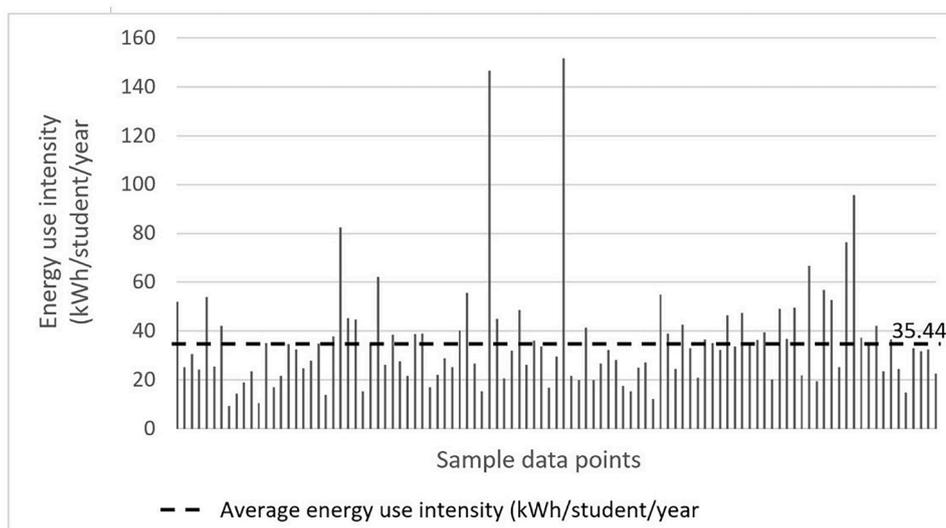
Fig. 4. Energy use intensity per student.

duration is 16 weeks. While the first semester regularly begins in mid-September and ends in January, the second semester begins in February and ends in June. The average daily occupancy period is around 5 h/day, with school operations occurring across a standard 5-day workweek, this yields an annual occupancy in the average of 800 h/year. It is worth noting that assessing the reported results considering energy use patterns and users of energy in school buildings underpins the reported low energy use intensity in this research.

6. Conclusion

This research paper presents an empirical evidence for the actual energy consumption in public school buildings in the West Bank. Actual energy consumption data for a randomly selected representative sample consisting of 103 public schools was statistically analyzed to develop a baseline for energy consumption in public school buildings.

The energy use intensity in school buildings in the West Bank was found to be 8.35 kWh/m^2/year and 35.44 kWh/student/year. Education buildings are generally low energy intensive facilities compared to other categories of buildings (Melo et al., 2023). Notwithstanding, these results are far below similar results reported in the literature from other countries, and can be justified by the absence of air conditioning and heating systems in classrooms.

The results reported in this research suggest that zero energy targets can be achieved in school buildings through utilizing on-site energy production technologies such as photovoltaic. The total energy demand can be covered through renewable energy technologies with a potential of excess production which can be utilized to incorporate heating and cooling features in school buildings.

The development of an energy consumption baseline for school buildings is a critical step towards promoting sustainability and energy efficiency in educational buildings. It helps in identifying energy saving areas. Furthermore, it helps in evaluating simulated energy performance during the design phase of school buildings.

In the past 10 years, there is an increasing attention to the concept of green building in the Palestinian marketplace. The findings of this research help decision makers to formulate suitable strategies and policies that suit the Palestinian case in terms of school buildings' performance. The established energy consumption baseline for public schools can be utilized as a benchmark to evaluate the actual energy demand in the first green school in Palestine and also to encourage energy retrofits for the existing school buildings to benefit from onsite renewable energy production technologies.

CRediT authorship contribution statement

Sawsan Dmaidi: Writing – review & editing, Writing – original draft, Resources, Methodology, Formal analysis, Data curation. **Luay N. Dwaikat:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Formal analysis. **Muhannad Haj Hussein:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data are available in the manuscript.

Appendix

Table 2

Collected data and data analysis for the research sample.

No.	School	City	Males or females school	Number of male students	Number of female students	Total students number	Gross school Area (m^2)	Average annual energy consumption (kWh/year)	Energy use intensity per unit area (kWh/m^2/year)	Energy use intensity per student (kWh/Student/year)
1	Al-Imam Al-Shafi'e Elementary School	Nablus	Females	–	74	74	253	3854.40	15.23	52.09
2	Sameer Sa'ad El-din Secondary School	Nablus	Females	–	574	574	2546	14,467.80	5.68	25.21
3	Abdulmagith Al - Ansari Elementary Boys	Nablus	Males	247	–	247	1625	7513.60	4.62	30.42
4	Khadijah um Al-Mominen Mixed Elementary School	Nablus	Mixed	82	82	164	323	3960.20	12.26	24.15
5	Yousuf Barqawi Elementary School	Nablus	Males	100	–	100	598	5394.20	9.02	53.94
6	IRAQ AL-Tayah Secondary Girls School	Nablus	Females	–	435	435	2064	11,048.80	5.35	25.40
7	Zeinabiyeh Elementary Boys School	Nablus	Males	70	–	70	200	2948.60	14.74	42.12
8	Khansa Elementary Girls School	Nablus	Females	–	486	486	368	4459.20	12.12	9.18
9	Yasid Secondary Girls School	Nablus	Females	–	284	284	1250	4096.80	3.28	14.43
10	Azmout Elementary School for Girls	Nablus	Females	–	154	154	450	2903.60	6.45	18.85
11	Kamal Jumblatt Secondary School	Nablus	Females	–	527	527	3025	12,384.80	4.09	23.50
12	Azmout Secondary School for Boys	Nablus	Males	440	–	440	1892	4585.60	2.42	10.42
13	Aben-Sena'a Elementary School	Nablus	Females	–	161	161	640	5672.60	8.86	35.23
14	Al-itihad Elementary Boys School	Nablus	Males	215	–	215	965	3657.20	3.79	17.01
15	Abdul Rahim Jardaneh Secondary Boys School	Nablus	Males	464	–	464	1453	10,060.40	6.92	21.68
16	Jamal Al - Masri Elementary Girls School	Nablus	Females	–	399	399	1747	13,857.20	7.93	34.73
17	Qusin Secondary School for Girls	Nablus	Females	–	206	206	504	6667.60	13.23	32.37
18	Al-Nizamiah Elementary School	Nablus	Females	–	154	154	1000	3791.60	3.79	24.62
19	Yasser Arafat Secondary Girls School	Nablus	Females	–	572	572	5000	15,873.20	3.17	27.75
20	Fatimiya Secondary School for Girls	Nablus	Females	–	331	331	1970	11,540	5.86	34.86
21	Kfarqaleel Secondary School for Girls	Nablus	Females	–	340	340	505	4754.40	9.41	13.98
22	Saad bin Abi Waqas Elementary Mixed School	Nablus	Mixed	122	131	253	723	9581	13.25	37.87
23	Alnizamia A Elementary School for girls	Nablus	Females	–	65	65	330	5350.80	16.21	82.32
24	Borhan Kamaal Elementary School	Nablus	Males	158	–	158	1092	7143.60	6.54	45.21
25	Zafer Al Masri Secondary School for Girls	Nablus	Females	–	275	275	1225	12,295.80	10.04	44.71
26	Bassam Shakaa Elementary School for Boys	Nablus	Males	715	–	715	1700	10,860.80	6.39	15.19
27	Ruhi Al-Hindi Elementary School	Nablus	Males	140	–	140	1300	4837.60	3.72	34.55

Table 2 (*continued*)

No.	School	City	Males or females school	Number of male students	Number of female students	Total students number	Gross school Area (m²)	Average annual energy consumption (kWh/year)	Energy use intensity per unit area (kWh/m²/year)	Energy use intensity per student (kWh/Student/year)
28	Zeinabia Elementary School for Girls	Nablus	Females	–	52	52	500	3226	6.45	62.04
29	Omar Al - Mukhtar Elementary Girls School	Nablus	Females	–	260	260	908	6777.20	7.46	26.07
30	Haj Muhammed Ali Qarm'an Elementary School	Nablus	Males	427	–	427	2150	16,458	7.65	38.54
31	Muhammed bin Rashid All Maktom Elementary School	Nablus	Males	193	–	193	2640	5327.20	2.02	27.60
32	Aisha Secondary School for Girls	Nablus	Females	–	474	474	1140	10,215	8.96	21.55
33	Sae'ed Bin Amir Secondary School	Nablus	Females	–	256	256	1510	9923.80	6.57	38.76
34	Muscat Mixed Secondary School / Bayt Iba	Nablus	Mixed	245	42	287	2046	11,190	5.47	38.99
35	Deir Al-Hatab Elementary School	Nablus	Males	627	–	627	1845	10,619.20	5.76	16.94
36	Carmel Secondary School for Girls	Nablus	Females	–	282	282	1680	6219	3.70	22.05
37	Talouzeh Secondary Mixed School	Nablus	Mixed	230	18	248	1400	7127.80	5.09	28.74
38	Alshahida Muntaha Hourani Elementary School for Girls	Jenein	Females	–	223	223	1000	5604.20	5.60	25.13
39	Jenein Secondary School for Boys	Jenein	Males	311	–	311	1050	12,519.60	11.92	40.26
40	Yamoun Secondary School for Boys	Jenein	Males	346	–	346	3000	19,269.40	6.42	55.69
41	Nusseibeh Almaznieh Elementary School for Girls	Jenein	Females	–	398	398	1570	10,579.40	6.74	26.58
42	Salah Khallaf Elementary school	Jenein	Males	171	–	171	380	2597.80	6.84	15.19
43	Jenein Industrial Secondary School*	Jenein	Males	275	–	275	3310	40,344.40	12.19	146.71
44	Hitteen Secondary School for Boys	Jenein	Males	239	–	239	780	10,727.60	13.75	44.89
45	Hitteen Elementary School for Boys	Jenein	Males	569	–	569	2100	11,748.20	5.59	20.65
46	Qasem Mohammed Qasem Elementary Mixed School	Jenein	Mixed	82	152	234	1100	7455.50	6.78	31.86
47	Al-Salam Secondary School for Boys	Jenein	Males	292	–	292	1272	14,184.80	11.15	48.58
48	Alshahida Kadoura Moussa Elementary School for Girls	Jenein	Females	–	362	362	1434.70	9501.60	6.62	26.25
49	Malaysian Friendship Secondary School for Girls	Jenein	Mixed	74	313	387	1698	13,941.40	8.21	36.02
50	Al - Zahraa Secondary School for Girls	Jenein	Females	–	454	454	2100	15,242.20	7.26	33.57
51	Haifa Elementary school for Girls	Jenein	Females	–	329	329	1720	5550.40	3.23	16.87
52	Yamoun Secondary School for Girls	Jenein	Females	–	505	505	2000	14,982.80	7.49	29.67
53	Banat Shuhada'a Al-Yamon Elementary school	Jenein	Females	–	91	91	300	13,817	46.06	151.84
54	Al-Malaysia Elementary School for Girls	Jenein	Mixed	120	339	459	2250	9943.80	4.42	21.66

Table 2 (*continued*)

No.	School	City	Males or females school	Number of male students	Number of female students	Total students number	Gross school Area (m^2)	Average annual energy consumption (kWh/year)	Energy use intensity per unit area (kWh/m^2/year)	Energy use intensity per student (kWh/Student/year)
55	Amna Bint Wahab School for Girls	Jenein	Females	–	572	572	2499	11,432.33	4.57	19.99
56	Al-Zahra Elementary Girls School	Jenein	Females	–	531	531	864	21,957.60	25.41	41.35
57	Palestinian - Turkish Friendship Girls School	Jenein	Mixed	73	349	422	1740	8412	4.83	19.93
58	Al - Ibrahimin Secondary Girls School	Jenein	Females	–	427	427	1677	11,375.20	6.78	26.64
59	Walid Abu Mowais Elementary Girls School	Jenein	Females	–	406	406	1364	13,050.20	9.57	32.14
60	Al-Salhin Elementary Boys School	Jenein	Males	385	–	385	2784	10,840.60	3.89	28.16
61	Mohammad Arshid Yassin Elementary Boys School	Jenein	Males	301	–	301	1700	5261.80	3.10	17.48
62	Anin Elementary Girls School	Jenein	Females	–	259	259	1630	3975.20	2.44	15.35
63	Kfardan Elementary Girls School	Jenein	Females	–	582	582	3000	14,570.20	4.86	25.03
64	Somayya Bent Al-Khayyat Elementary School	Jenein	Females	–	510	510	2415	13,817	5.72	27.09
65	Kafr Dan Elementary School for Boys	Jenein	Males	371	–	371	1106	4525	4.09	12.20
66	Almazraa Alqablia Secondary Boys School	Ramallah	Males	74	–	74	1675	4071.50	2.43	55.02
67	Mashhour Haditha El Jazy Secondary Girls School	Ramallah	Females	–	254	254	2281	9883.50	4.33	38.91
68	shuhada Silwad Secondary School for Boys	Ramallah	Males	457	–	457	2637	11,173.80	4.24	24.45
69	Saffa Elementary boys School	Ramallah	Males	238	–	238	1000	10,150.80	10.15	42.65
70	Al-Tirah Mixed secondary School	Ramallah	Mixed	60	195	255	1337.22	8402.60	6.28	32.95
71	Abwain Secondary Mixed School	Ramallah	Mixed	296	24	320	1480	6639.80	4.49	20.75
72	Alberah New Secondary Girls School	Ramallah	Females	–	554	554	3600	20,258.33	5.63	36.57
73	Petunia Secondary Girls School	Ramallah	Females	–	408	408	700	14,306	20.44	35.06
74	Ni'lin Secondary Boys School	Ramallah	Males	406	–	406	1753	13,118	7.48	32.31
75	Bil'in Secondary Girls School	Ramallah	Females	–	245	245	1640	11,352.60	6.92	46.34
76	Mughtaribi Alberah mixed basic beer	Ramallah	Mixed	154	179	333	2634	11,206.60	4.25	33.65
77	Birzeit High Elementary Boys School	Ramallah	Males	316	–	316	1765.16	14,989.60	8.49	47.44
78	Bettain Secondary School for Boys	Ramallah	Males	178	–	178	564	6253.40	11.09	35.13
79	Ras Karkar Secondary Mixed School	Ramallah	Mixed	86	252	338	2197	12,248	5.57	36.24
80	Ain Yabroud Mixed Elementary School	Ramallah	Mixed	80	103	183	600	7214.60	12.02	39.42
81	Beitlo Secondary Mixed School	Ramallah	Mixed	370	37	407	1630	8154.80	5	20.04
82	singel Elementary Girls School	Ramallah	Females	–	249	249	1000	12,250.40	12.25	49.20
83	Sorda Mixed Elementary School	Ramallah	Mixed	86	82	168	1114	6181.80	5.55	36.80

Table 2 (*continued*)

No.	School	City	Males or females school	Number of male students	Number of female students	Total students number	Gross school Area (m²)	Average annual energy consumption (kWh/year)	Energy use intensity per unit area (kWh/m²/year)	Energy use intensity per student (kWh/Student/year)
84	Burqa Secondary Mixed School	Ramallah	Mixed	188	18	206	600	10,226	17.04	49.64
85	Deir Abu Mishaal Secondary Girls School	Ramallah	Females	–	329	329	1166	7165.60	6.15	21.78
86	Jalgilia Mixed Elementary School	Ramallah	Mixed	49	60	109	820	7269.20	8.86	66.69
87	shabtin Secondary mixed School	Ramallah	Mixed	168	156	324	1520	6301.20	4.15	19.45
88	Abu Obeida Elementary Girls School *	Ramallah	Females	–	586	586	900	33,242.60	36.94	56.73
89	Kubbar Elementary School for Boys	Ramallah	Males	186	–	186	1440	9789.20	6.80	52.63
90	Deir-Greer Secondary Boys school	Ramallah	Males	212	–	212	1235	5363.60	4.34	25.30
91	Ain-munjed Elementary School for Boys*	Ramallah	Males	527	–	527	2064	40,313.40	19.53	76.50
92	Qarawah Secondary Girls School*	Ramallah	Females	–	253	253	2822	24,233	8.59	95.78
93	Kharbatha Bani Harith Secondary Girls School	Ramallah	Females	–	276	276	1000	10,286	10.29	37.27
94	Kubbar Secondary School for Girls	Ramallah	Females	–	113	113	386	3932.40	10.19	34.80
95	Almazraa Alqablia Mixed Elementary School	Ramallah	Mixed	84	178	262	500	11,011.60	22.02	42.03
96	Abu Falah Secondary School for Boys	Ramallah	Males	263	–	263	15,130	6174.60	0.41	23.48
97	alfajr aljadid Mixed Elementary School	Ramallah	Mixed	126	282	408	1000	14,935.80	14.94	36.61
98	Shuqba Mixed Elementary School	Ramallah	Mixed	319	282	601	2518	14,672	5.83	24.41
99	Majida and Seela Girls secondary School	Ramallah	Females	–	282	282	2000	4206.40	2.10	14.92
100	Deir Ammar Secondary Girls School	Ramallah	Females	–	321	321	1200	10,610.60	8.84	33.05
101	Singel High Elementary Males School	Ramallah	Males	434	–	434	1332	13,769	10.34	31.73
102	Al-Janiah Mixed secondary School	Ramallah	Mixed	60	119	179	4600	5830.40	1.27	32.57
103	Kfar Naama Secondary Mixed School	Ramallah	Mixed	528	41	569	2645	12,805	4.84	22.50
	Sum					33,343	172,896.08	1067,865.57	859.18	3650.65
	Average					323.72	1678.60	10,367.63	8.35	35.44

* Electricity consumption outliers, not excluded from the analysis.

References

Abu Bakar, N.N., Hassan, M.Y., Abdullah, H., Rahman, H.A., Abdullah, M.P., Hussin, F., Bandi, M, 2015. Energy efficiency index as an indicator for measuring building energy performance: a review. Renew. Sustain. Energy Rev. 44, 1–11. https://doi.org/10.1016/j.rser.2014.12.018.

Adams, W.M. (2006). The future of sustainability re-thinking environment and development in the twenty-first century, Report of the IUCN Renowned Thinkers Meeting (Issue January). International Union for Conservation of Nature (IUCN). http://cmsdata.iucn.org/downloads/iucn_future_of_sustainability.pdf.

Alajmi, A., Abou-ziyan, H., Ghoneim, A., 2016. Achieving annual and monthly net-zero energy of existing building in hot climate. Appl. Energy 165, 511–521. https://doi.org/10.1016/j.apenergy.2015.11.073.

Bartlett, J.E., Kotrlik, J.W.K.J.W., Higgins, C., 2001. Organizational research: determining appropriate sample size in survey research. Inf. Technol. Learn. Perform. J. 19 (1), 43.

Breysse, J., Jacobs, D.E., Weber, W., Dixon, S., Kawecki, C., Aceti, S., Lopez, J., 2011. Health outcomes and green renovation of affordable housing. Public Health Rep. 126 (1_suppl), 64–75. https://doi.org/10.1177/00333549111260S110.

Calì, D., Osterhage, T., Streblow, R., Müller, D., 2016. Energy performance gap in refurbished German dwellings: lesson learned from a field test. Energy Build. 127, 1146–1158. https://doi.org/10.1016/j.enbuild.2016.05.020.

Chung, W., 2011. Review of building energy-use performance benchmarking methodologies. Appl. Energy 88 (5), 1470–1479. https://doi.org/10.1016/j.apenergy.2010.11.022.

Daly, D., Roth, J., Kokogiannakis, G., McDowell, C., Tibbs, M., Cooper, P., 2022. Energy consumption in Australian primary schools: influences and metrics. Energy Build. 277, 112549 https://doi.org/10.1016/j.enbuild.2022.112549.

de Oliveira Veloso, A.C., Gonçalves de Souza, R.V., dos Santos, F.N., 2020. Energy benchmarking for office building towers in mild temperate climate. Energy Build. 222, 12–14. https://doi.org/10.1016/j.enbuild.2020.110059.

de Wilde, P., 2014. The gap between predicted and measured energy performance of buildings: a framework for investigation. Autom. Constr. 41, 40–49. https://doi.org/10.1016/j.autcon.2014.02.009.

Evans, G.W., 2003. The built environment and mental health. J. Urban Health 80 (4), 536–555. https://doi.org/10.1093/jurban/jtg063.

Free, S., Howden-Chapman, P., Pierse, N., Viggers, H., 2010. More effective home heating reduces school absences for chilien with asthma. J. Epidemiol. Community Health 64 (5), 379–386. https://doi.org/10.1136/jech.2008.086520.

GhaffarianHoseini, A., Dahlan, N.D., Berardi, U., GhaffarianHoseini, A., Makaremi, N., GhaffarianHoseini, M., 2013. Sustainable energy performances of green buildings: a review of current theories, implementations and challenges. Renew. Sustain. Energy Rev. 25, 1–17. https://doi.org/10.1016/j.rser.2013.01.010.

Hernandez, P., Burke, K., Lewis, J.O., 2008. Development of energy performance benchmarks and building energy ratings for non-domestic buildings: an example for Irish primary schools. Energy Build. 40 (3), 249–254. https://doi.org/10.1016/j.enbuild.2007.02.020.

Hodiri, H., 2018. Assessing the Actual Performance of Green Buildings in Palestine: a Case Study. An-Najah National University. Master's Thesis.

International Energy Agency. (2021). Total final consumption (TFC) by sector, World 1990-2018. Data and Statistics. https://www.iea.org/data-and-statistics/data-browser?country=WORLD&fuel=Energyconsumption&indicator=TFCShareBySector.

ISO. (2014). ISO 50006:2014- Energy management systems - Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) - General principles and guidance title. https://www.iso.org/standard/51869.html.

John, M. (2015). What is a baseline? And why it's critical to good energy management.

Katafygiotou, M.C., Serghides, D.K., 2014. Analysis of structural elements and energy consumption of school building stock in Cyprus: energy simulations and upgrade scenarios of a typical school. Energy Build. 72, 8–16. https://doi.org/10.1016/j.enbuild.2013.12.024.

Keeble, B.R., 1988. The Brundtland report: "Our common future.". Med. War 4 (1), 17–25. https://doi.org/10.1080/07488008808408783.

Kibert, C.J., 2012. Sustainable Construction: Green Building Design and Delivery, 3rd ed. John Wiley & Sons Inc.

Kibert, C.J., 2016. Sustainable Construction: Green Building Design and Delivery, 4th ed. John Wiley & Sons Inc.

Kim, T., Kang, B., Kim, H., Park, C., Hong, W.H., 2019. The study on the energy consumption of middle school facilities in Daegu, Korea. Energy Rep. 5, 993–1000. https://doi.org/10.1016/j.egyr.2019.07.015.

Magzamen, S., Mayer, A.P., Barr, S., Bohren, L., Dunbar, B., Manning, D., Reynolds, S.J., Schaeffer, J.W., Suter, J., Cross, J.E., 2017. A multidisciplinary research framework on green schools: infrastructure, social environment, occupant health, and performance. J. School Health 87 (5), 376–387. https://doi.org/10.1111/josh.12505.

Melo, F.C., Carrilho da Graça, G., Oliveira Panão, M.J.N., 2023. A review of annual, monthly, and hourly electricity use in buildings. Energy Build. 293, 113201 https://doi.org/10.1016/j.enbuild.2023.113201.

Moghimi, S., Azizpour, F., Mat, S., Lim, C.H., Salleh, E., Sopian, K., 2014. Building energy index and end-use energy analysis in large-scale hospitals—Case study in Malaysia. Energy Effic. 7 (2), 243–256. https://doi.org/10.1007/s12053-013-9221-y.

Naing, L., Winn, T., Rusli, B.N., 2006. Practical issues in calculating the sample size for prevalence studies. Arch. Orofac. Sci. 1 (1), 9–14.

National Research Council, 2007. Green Schools: Attributes for Health and Learning. The National Academies Press. https://doi.org/10.17226/11756.

Ouf, M.M., Issa, M.H., 2017. Energy consumption analysis of school buildings in Manitoba, Canada. Int. J. Sustain. Built Environ. 6 (2), 359–371. https://doi.org/10.1016/j.ijsbe.2017.05.003.

Palestinian Engineers Association, 2013. Green Buildings Guidelines – State of Palestine. Palestinian Engineers Association publications.

Thompson, S.K., 2012. Sampling, 3rd ed. John Wiley & Sons, Inc.

UNDP. (2015). Building sector energy effeciency project (BSEEP). United Nations Environment Programme (UNEP). http://www.my.undp.org/content/dam/malaysia/docs/Building-Sector-Energy-Efficiency-Projects-Prodoc.pdf.

UNEP, 2020. 2020 global status report for buildings and construction: Towards a Zero-emission. Efficient and Resilient Buildings and Construction Sector - Executive Summary. United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/34572/GSR_ES.pdf.

Wang, J.C., 2016. A study on the energy performance of school buildings in Taiwan. Energy Build. 133, 810–822. https://doi.org/10.1016/j.enbuild.2016.10.036.

Weiss, N.A., 2012. Elementary Statistics, 8th ed. Pearson Education, Inc.

Yudelson, J., 2008. The Green Building Revolution. Island Press.

Zuo, J., Zhao, Z.Y., 2014. Green building research-current status and future agenda: a review. Renew. Sustain. Energy Rev. 30, 271–281. https://doi.org/10.1016/j.rser.2013.10.021.