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John R. Littlewood
Robert J. Howlett
Lakhmi C. Jain *Editors*

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John R. Littlewood · Robert J. Howlett ·
Lakhmi C. Jain
Editors

Sustainability in Energy and Buildings 2021

Springer

Editors
John R. Littlewood
Cardiff Metropolitan University
Cardiff, South Glamorgan, UK

Robert J. Howlett
KES International
Shoreham-by-Sea, North Yorkshire, UK

Lakhmi C. Jain
KES International
Shoreham-by-Sea, North Yorkshire, UK

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Preface

The 13th International Conference on Sustainability and Energy in Buildings 2021 (SEB-21) is a major international conference organized by a partnership made up of KES International and The Sustainable and Resilient Built Environment group, Cardiff Metropolitan University.

SEB-21 invited contributions on a range of topics related to sustainable buildings and renewable energy and explored innovative themes regarding building adaptation responding to climate change.

The aim of the conference was to bring together university researchers, government and scientific experts and industry professionals to discuss the minimization of energy use and associated carbon emissions in buildings, neighbourhoods and cities, from a theoretical, practical, implementation and simulation perspective. The conference formed an exciting chance to present, interact and learn about the latest research and practical developments on the subject. This is the second time that SEB-21 had held virtually, and this has been made necessary because of the ongoing COVID-19 pandemic which has swept the world.

The conference featured two general tracks chaired by experts in the fields:

- Sustainable and Resilient Buildings
- Sustainable Energy Technologies.

In addition, there were seventeen Invited sessions proposed and organised by prominent researchers.

It is important that a conference provides high-quality talks from leading-edge presenters. SEB-21 featured two keynote speakers: Dr. Clayton Miller, National University of Singapore, Singapore, and Prof. Liz Varga, University College London (UCL), UK.

The conference attracted submissions from around the world. Submissions for the full-paper track were subjected to a two-stage blind peer review process. With the objective of producing a high-quality conference, only the best of these were selected for presentation at the conference and publication in Springer as chapters. Submissions for the short paper track were subjected to a 'lighter-touch' review and published in an online medium, but not in Springer book.

Thanks are due to the very many people who have given their time and goodwill freely to make SEB-21 a success. We would like to thank the members of the International Programme Committee who were essential in providing their reviews of the conference papers, ensuring appropriate quality. We thank the high-profile keynote speakers for providing interesting talks to inform delegates and provoke discussion. Important contributors to the conference were made by the authors, presenters and delegates without whom the conference could not have taken place, so we offer them our thanks. Finally, we would like to thank the administrative staff of KES International.

It is hoped that you find the conference an interesting, informative and useful experience and remain connected through the KES International Virtual Conference Experience.

Dr. John R. Littlewood
Cardiff Metropolitan University
Cardiff, Wales, UK

Prof. Robert J. Howlett
'Aurel Vlaicu' University of Arad
Arad, Romania

Bournemouth University
Poole, UK

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About the Editors

Dr. John R. Littlewood graduated in Building Surveying, holds a Ph.D. in Building Performance Assessment of Zero Heating Housing and is a Chartered Building Engineer. He is Head of the Sustainable and Resilient Built Environment Research group in Cardiff School of Art & Design and the Human Centred Design Global Academy, at Cardiff Metropolitan University (UK). He coordinates three Professional Doctorates in Art and Design, Engineering and Sustainable Built Environment, and has supervised and examined to completion 11 and 18 doctorates. His research is industry focussed, investigating methods to optimize the fire, production and thermal performance for existing and new dwellings during the design, manufacture, construction, operation or during and after retrofit stages. His current research includes working with Wales' largest offsite manufacturer of timber frame construction systems to increase the use of natural materials and recycling to embrace the circular economy. The outcomes of his research enhance occupant quality of life and increase the environmental sustainability and resilience of the built environment. He has authored, co-authored and co-edited 155 academic peer-reviewed publications and supported the SEB international conference series since 2010.

Dr. Robert J. Howlett is Executive Chair of KES International, a non-profit organization that facilitates knowledge transfer and the dissemination of research results in areas including intelligent systems, sustainability and knowledge transfer. He is Visiting Professor at Bournemouth University in the UK. His technical expertise is in the use of intelligent systems to solve industrial problems. He has been successful in applying artificial intelligence, machine learning and related technologies to sustainability and renewable energy systems; condition monitoring, diagnostic tools and systems; and automotive electronics and engine management systems. His current research work is focussed on the use of smart microgrids to achieve reduced energy costs and lower carbon emissions in areas such as housing and protected horticulture.

Dr. Lakhmi C. Jain Ph.D., M.E., B.E. (Hons), Fellow (Engineers Australia), was with the University of Technology Sydney, Australia, and presently serving the Liverpool Hope University, UK. He founded the KES International for providing a professional community the opportunities for publications, knowledge exchange, cooperation and teaming. Involving around 5000 researchers drawn from universities and companies worldwide, KES facilitates international cooperation and generate synergy in teaching and research. KES regularly provides networking opportunities for professional community through one of the largest conferences of its kind in the area of KES.

Examining the Deviation in Energy Saving Estimations Due to the Use of the Degree Days Method

Ahmed Mokhtar

Abstract Energy performance contracts are commonly used to retrofit buildings and reduce their energy consumption. The financial agreement in the contracts typically depends on calculating the amount of energy saved every year. This is difficult to calculate as many aspects that impact a building's energy consumption continuously change, including the weather. The Degree Days method is commonly used to help estimate the energy saving while the weather is changing. The Degree Days can be calculated with a variety of base temperatures resulting in different values. This paper is a first step in examining the significance of the deviation in energy saving calculations when using this method. It also investigates if there is a more appropriate base temperature to use for that purpose. Energy simulation with actual annual weather data is used to make the investigation. Two different building types and three different energy conservation measures are used. The results of this preliminary investigation show that the deviation can be significant in some cases. They also show the possibility that a particular base temperature for calculating the degree days can give more accurate savings estimations. These can be very important results for users of energy performance contracts.

1 Introduction

With the signing of the Paris Agreement on climate change, several countries initiated programs to retrofit old buildings to reduce their energy consumption. In addition, many owners see a financial benefit in improving the energy performance of their buildings by reducing their energy bill. As a result, energy service companies (ESCO) are offering various services to accommodate this market demand. An important part of these services is the energy performance contract [1]. These are contracts that aim to finance the retrofitting cost by using the savings in the energy consumption cost. There are basically two common types of energy performance contracts between

A. Mokhtar (✉)
American University of Sharjah, 26666 Sharjah, United Arab Emirates
e-mail: mokhtar@aus.edu

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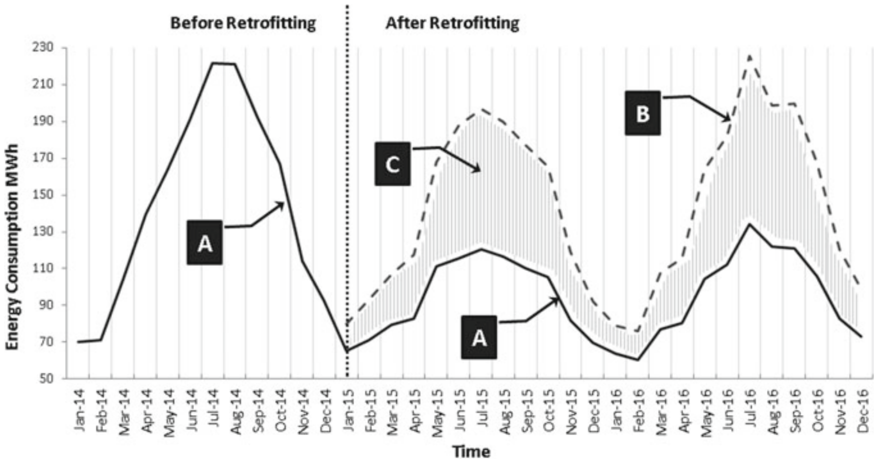

Fig. 1 Building energy consumption before and after retrofitting. **a** is actual consumption. **b** is estimated consumption if there was no retrofitting. **c** is the estimated saving in energy consumption

an owner and an ESCO. These are the Guaranteed Savings contract and the Shared Savings contract. In a simplified way, the main difference between these two types of contracts is in the financing of the retrofitting cost and in the calculations of the savings. In a Guaranteed Savings contract, the owner finances the retrofitting cost and pays the ESCO for their technical service. However, the payment is due only when a certain level of energy consumption saving is achieved from the retrofitting. In a Shared Savings contract, the ESCO finances the retrofitting costs in return for a percentage of the saving in the consumption cost. In both types of contracts, the saving in energy needs to be determined to process the payments according to the contract.

The problem is that energy savings is not a measurable quantity. Rather, it is an estimated one. Figure 1 illustrates this problem. What can be measured is the energy consumption because it is metered. We can measure it before retrofitting and after retrofitting. Line (A) shows this metered energy consumption. It is certainly easy to assume that—if the retrofitting is not done—the building would have consumed the same energy that we measured before its retrofitting. Hence, the difference between what we measure before retrofitting (the part of line A before retrofitting) and what we measure after retrofitting (the part of line A after retrofitting) is what is being saved. Yet, this is not correct. Several factors affect the building which results in a variation in energy consumption every year. These include changes in the schedule of the building use or in the number of its occupants among many other factors. Therefore, we need to establish an estimation of what would have been the building's energy consumption if it was not retrofitted. Line (B) in Fig. 1 shows an example of this estimation. Using estimated energy consumption (B), and the metered energy consumption (A), we can establish a more accurate estimation of the energy saving due to the retrofitting. This will be the difference between (B) and (A) as represented by the area (C) in

Fig. 1. As mentioned above, the estimation in savings has contractual and financial implications for both parties involved in the energy performance contracts. The more accurate the actual saving calculation is, the clearer are the contractual obligations and the fairer is the distribution of saved money.

The challenge now is in estimating line (B) for a particular building reasonably accurately. Several methods exist to make such estimation as defined by the International Performance Measurement and Verification Protocol (IPMVP) [2]. The amount of data needed and the effort and money put in collecting different data varies between these methods. Depending on the nature of the building and the extent of the retrofit, a simple or more complex method is selected to help estimate the saving in energy consumption (C) in Fig. 1.

One of the most important factors that affect the variation in a building's energy consumption is the annual change in the weather conditions. In most buildings, this change has a direct impact on the energy consumption by the HVAC systems. Depending on the building type and its surrounding climate, these systems can be by far the biggest consumer of energy in a building. Hence, fluctuation in weather conditions means fluctuations in the building's annual energy consumption. To estimate the impact of weather in creating line (B) in Fig. 1, the "Degree Days" method is commonly used [3]. The method uses numbers that can be generated from weather data. These numbers change as the weather changes. A simple equation can be used then to estimate line (B) in Fig. 1 from the section of line (A) that is before retrofitting. For example, and following the timeline in Fig. 1, to estimate the energy that the building would have consumed if it were not retrofitted in the year 2015 (E_{Est}), get the energy actually used by the building before retrofitting in year 2014 (E_{Base}) which is considered the base (or reference) year, get the cooling degree days for 2015 (CDD_{Est}) and the cooling degree days for 2014 (CDD_{Base}) and use these in Eq. (1).

$$(E_{Est}) = (E_{Base}) * \frac{CDD_{Est}}{CDD_{Base}} \tag{1}$$

The question now is how to calculate the values for the CDD in the needed years. According to Bromley [4], "*Degree days are a measure of how much (in degrees), and for how long (in days), the outside air temperature was below [above] a certain level*". In case of Heating Degree Days (HDD), we measure "below" a certain base temperature while in the case of Cooling Degree Days (CDD), we measure "above" a certain base temperature. HDD are used when we want to estimate the energy needed to heat a building while CDD are used when we want to estimate the energy needed to cool a building. The bigger the number, the more energy is expected to be used by the HVAC system to achieve human thermal comfort. In this article, we focus on using the CDD.

Calculating the CDD requires a base temperature. This is the temperature above which we assume the building requires cooling. The standard base temperature used in ASHRAE is 18.3 °C (65 °F). However, others use different base temperatures. Azevedo et al. [5] provides a list of base temperatures used in different countries as they appear in the literature. The list shows a variation from 18 to 28 °C and it reflects the assumptions made by the different researchers on the temperature beyond which a building needs to be cooled mechanically. This certainly depends on the type of building and its climatic region.

Once the base temperature is determined, calculating the CDD for a particular period (e.g. month or year) is simple. Using the hourly weather data, a value "X_i" is calculated for each day using Eq. (2). All the positive values for "X_i"—for the number of hours "h" that are in the calculated period—are summed to be the CDD for the needed period as shown in Eq. (3).

$$X_i = \frac{\left(T_{Daily\ Max} - T_{Daily\ Min}\right)}{2} - T_{Base\ Temperature} \tag{2}$$

$$CDD = \sum_{i=1}^{h} \mathrm{X}_i \ \text{(where } \mathrm{X}_i > 0\text{)} \tag{3}$$

Clearly, the selection of the base temperature impacts the calculated CDD. Hence, the ratio CDD_{Est}/CDD_{Base} that is used in Eq. (1) will vary accordingly. Consequently, the estimated energy consumption E_{Est} that represents line (B) in Fig. 1 will also vary. Therefore, the estimated saving due to the retrofitting, (C) in Fig. 1, will be different each time we change the base temperature for calculating the CDD. This may affect the amount of money to be paid to the ESCO in the case of a shared savings contract. It may also result in non-payment in the case of a guaranteed savings contract.

This paper is a step towards answering two questions. The first is how big the deviation is in estimating the saving in energy consumption when the CDD method is used. The second is whether there is an optimal base temperature that minimizes the deviation. The paper starts by explaining the methodology used to answer the two questions and it then shows the results and the conclusion of the study.

2 Methodology

Energy saving can never be measured in reality. Therefore, the researcher approach to answering the two questions is to use energy simulation software. With simulation, it is possible to keep all the parameters that impact a building's energy consumption constant, with the exception of the parameters being tested. This allows us to isolate some parameters and hence evaluate the impact of their changes on the building's energy consumption. In our case, we need to do so to create lines (A) and (B) of Fig. 1.

A building is modeled in the energy modeling software IESVE [6]. The following series of simulations are run using the weather data for the city of Sharjah in the United Arab Emirates (ASHRAE Climate Zone 1B Very Hot–Dry):

1 A simulation is done using actual hourly weather data for a base year (e.g. 2014). This creates the part of line (A) that exists before retrofitting as shown

in Fig. 1. The sum of the calculated monthly energy consumption represents the base consumption value E_{Base} of Eq. (1). No particular reason for selecting 2014 as the base year. The author just wants to have four years of performance after retrofitting as a reasonable time for testing the possible deviation in results. Further studies should test different base years and more years after retrofitting.

2 A simulation is done using actual hourly weather data for the consecutive years. (e.g. 2015, 2016, 2017, 2018). This creates line (B) as shown in Fig. 1 based on simulation results.

3 Some Energy Conservation Measures (ECMs) are applied to the simulated building to represent a retrofit work done on the building. The simulation is run using the actual hourly weather data for the consecutive years. (e.g. 2015, 2016, 2017, 2018). This creates the part of line (A) that exists after retrofitting as shown in Fig. 1.

Using Eqs. (2) and (3), several CDD calculations are done using a spreadsheet macro developed by the researcher. The macro uses actual hourly weather data and a base temperature—defined by the user—to make the CDD calculations. The following CDD calculations are done using the weather data for the city of Sharjah in the United Arab Emirates:

1 CDD for the base year (e.g. 2014) and for a range of base temperatures from 15 to 25 °C. For each base temperature, this is the value needed for CDD_{Base} in Eq. (1). Table 1 shows the results.

2 CDD for the consecutive years (e.g. 2015, 2016, 2017, 2018) and for a range of base temperatures from 15 °C to 25 °C. For each base temperature, this is the value needed for CDD_{Est} in Eq. (1). Table 1 shows the results.

For each base temperature, and for each of the consecutive years, we calculate the ratio CDD_{Est}/CDD_{Base} of Eq. (1). We then use Eq. (1) to estimate the energy consumption if the building is not retrofitted. This will be line (B) in Fig. 1 based on the CDD method.

To compare the difference between generating line (B) of Fig. 1 by using the two methods, Fig. 2 shows line (B) as (Bs) in case it is generated by the simulation and as (Bc) in case it is generated by the CDD method. The line (Bc) will be different for each base temperature.

Table 1 Calculated CDD for different base temperatures

Base temp. °C	15	16	17	18	19	20	21	22	23	24	25
2014	*4792*	*4439*	*4087*	*3743*	*3413*	*3100*	*2804*	*2528*	*2271*	*2023*	*1791*
2015	4825	4473	4123	3777	3443	3123	2824	2540	2265	2002	1754
2016	4720	4367	4015	3667	3330	3012	2711	2423	2147	1892	1657
2017	4859	4509	4160	3814	3472	3148	2841	2551	2279	2026	1789
2018	4824	4471	4119	3776	3446	3130	2830	2544	2272	2017	1774

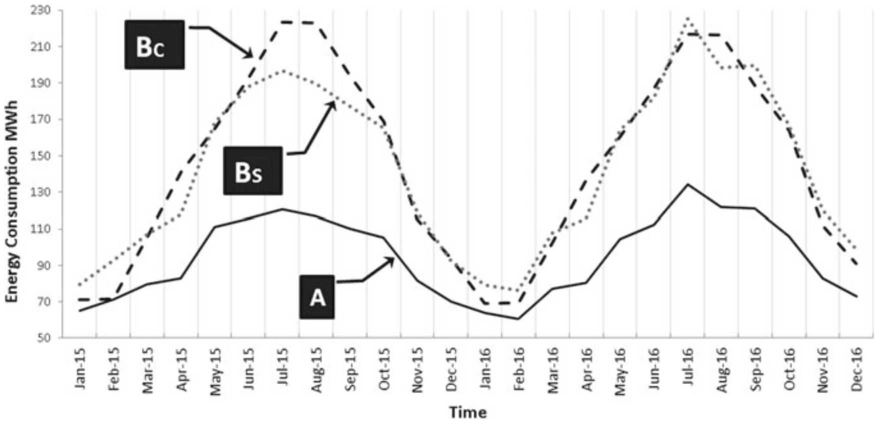

Fig. 2 Estimated energy consumption if no retrofitting is done. Bs is calculated using the computer simulation. Bc is calculated using the CDD method (shown here for base temperature = 18 °C)

Using Fig. 2, the estimated saving based on the simulation result will be the difference between the values in line (Bs) and the values in line (A) for each of the studied years (e.g. 2015, 2016, 2017, 2018). We will refer to this simulation-based saving value as ($S_{Simulation}$). Similarly, the estimated saving based on the CDD method will be the difference between the values in the line (Bc) and the values in line (A) for each of the studied years. We will refer to this CDD-based saving value as (S_{CDD}). The deviation in using the CDD method in estimating the energy saving is calculated using Eq. (4) for each year and for each of the used base temperatures from 15 to 25 °C as shown in Table 2.

$$Deviation = \frac{(S_{CDD} - S_{Simulation})}{S_{Simulation}} \quad (4)$$

The same process is repeated but for two types of buildings and for three types of ECMs. The objective is to check if the nature of the building and the used ECMs will make a meaningful difference. The buildings types are:

Table 2 Percentage of deviation in estimating energy saving when using the CDD method

Base temp. °C	15 (%)	16 (%)	17 (%)	18 (%)	19 (%)	20 (%)	21 (%)	22 (%)	23 (%)	24 (%)	25 (%)
2015	2.0	2.2	2.5	2.6	2.5	2.1	2.1	1.4	−0.6	−2.9	−5.8
2016	−4.3	−4.6	−5.0	−5.8	−7.0	−8.1	−9.5	−11.8	−15.5	−18.5	−21.5
2017	4.2	4.7	5.3	5.7	5.1	4.6	3.9	2.8	1.1	0.5	−0.3
2018	1.9	2.1	2.2	2.5	2.8	2.8	2.7	1.9	0.2	−0.8	−2.8
Ave. deviation	**1.0**	**1.1**	**1.2**	**1.3**	**0.9**	**0.3**	**−0.2**	**−1.4**	**−3.7**	**−5.4**	**−7.6**

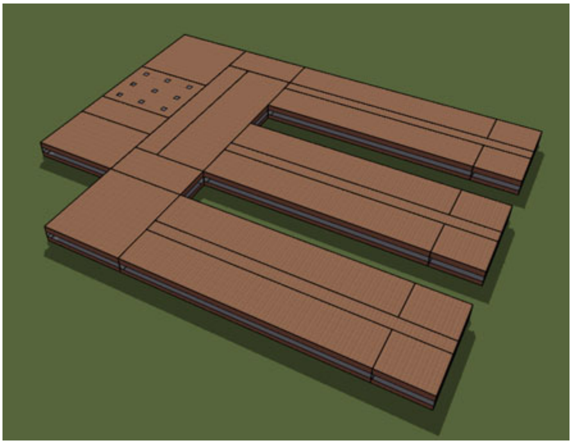

Fig. 3 The model for the primary school used

1 A primary school with a single floor and finger plan as shown in Fig. 3. Because of the form and the function of the building, it is considered to have an externally dominated cooling load and its energy performance is greatly impacted by the weather.
2 A hospital with a multi-story and deep plan as shown in Fig. 4. Because of the form and the function of the building, it is considered to have an internally dominated cooling load and its energy performance is less impacted by the weather.

Both modeled buildings are provided as templates by the software IES VE. The weather data for Sharjah is used for the years 2014 until 2018 and the cooling set point temperature is 24 °C. The three types of ECMs are:

1 ECMs directly related to the weather. The used ECMs are i) double the efficiency of the HVAC system used (from COP = 3.1 to COP = 6.2) and ii) double the R

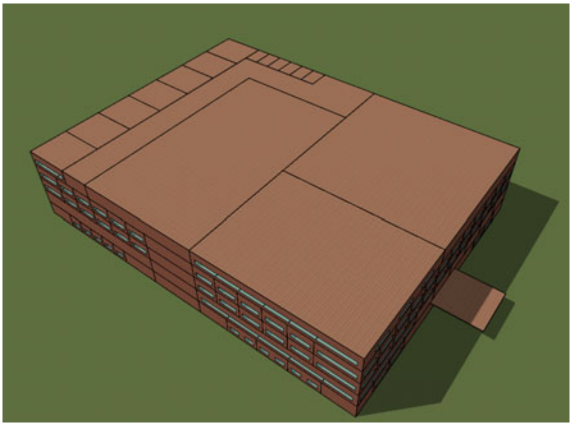

Fig. 4 The model for the hospital used

value of the roof (from R = 3.5 m^2°K/W to R = 7.0 m^2 °K/W). This is referred to as ECM (A).

2 ECMs not-directly related to the weather. The ECM used is replacing the florescent lighting with much more efficient LED light (The value for w/m^2 for each space is halved). This is referred to as ECM (C).

3 Both of the above ECMs are used. This is referred to as ECM (B).

The resulting consumption from the simulation in each case is the total building energy consumption and similarly is the estimated saving.

3 Results

Figure 5 shows the results of running the process for the school using the above mentioned three types of ECMs and for a range of base temperatures from 15 to 25 °C. The deviations have very different values for the same base temperature in

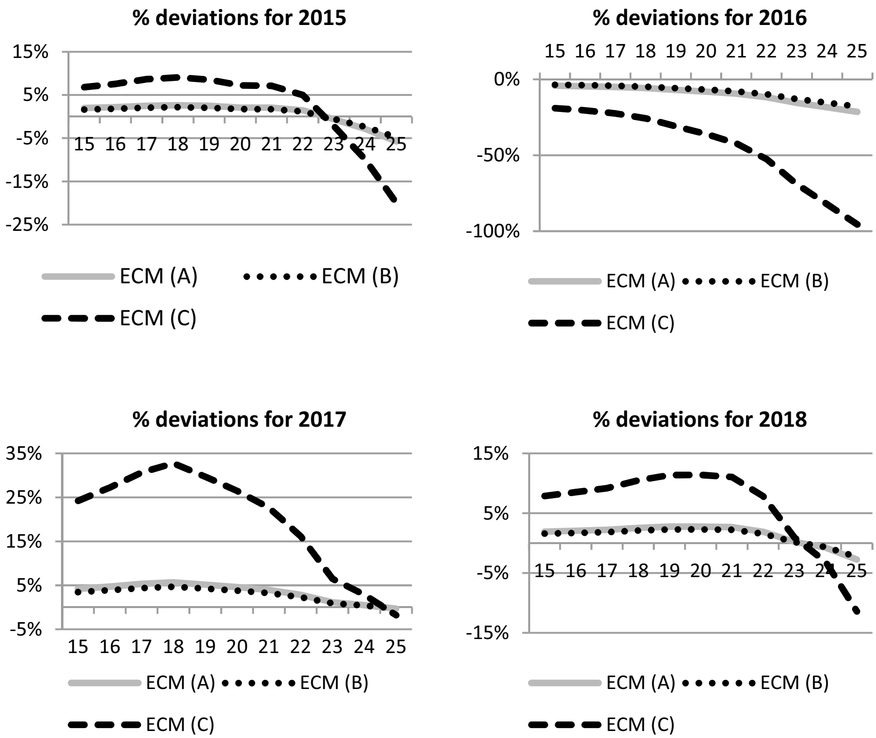

Fig. 5 Change in the % deviation in energy savings due to the change in CDD base temperature for the different types of ECMs and for the different years under study. Note the different scales for the % deviation

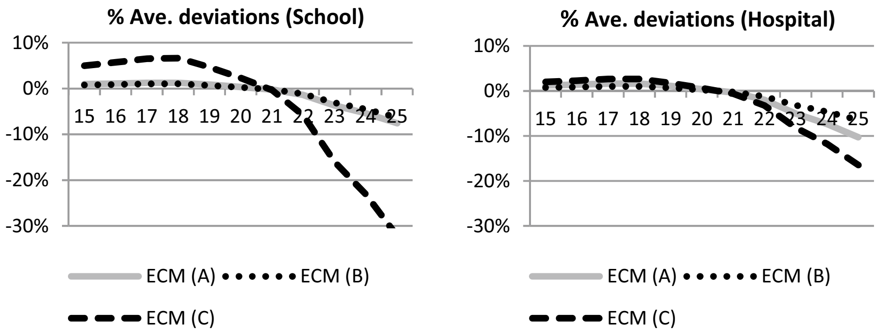

Fig. 6 Average of the % deviations for the four years under study, for the different types of ECMs, and for the two building types

each year. However, ECM (C) which is not-directly related to the weather, always shows much bigger deviation values. This confirms the need to have sub-metering for these types of ECMs and to not depend on the total consumption of energy to estimate the resulting savings. The % deviations for the other two types of ECMs barely exceed 5% except for the year 2016.

The % deviations tends to converge to zero near a particular base temperature. However, this temperature changes every year. This is with the exception of the year 2016 which had less CDD than that of 2014 regardless of the base temperature as it was in general a cooler year than the others. Its % deviations are getting bigger as the base temperature increases.

Figure 6 shows the % deviations when averaged over the four years. There is a trend that is appearing for both the school and the hospital. The % deviations are converging towards zero for the three types of ECMs around the temperature 21/21.5 °C even though one building is internally dominated and the other is externally dominated. This is an interesting observation and can lead to a guideline for selecting an appropriate base temperature for calculating the CDD for a particular city.

4 Conclusion

This preliminary examination of the deviation in energy saving estimations due to the use of the Degree Days method should encourage both owners and ESCO to identify a better base temperature to use. More studies need to be done for longer periods of time, for different cities, and for more building types to provide better guidance. It is also important to note that the % deviation in using the CDD method is generally low except for the type of ECMs that are not-directly related to the weather.

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Impact of Climate Zone and Orientation Angle on the Recurring Massing School Typologies in Turkey

Yasemin Afacan

Abstract In this study, the impact of different climate zones on same massing typologies of a typical school building with different orientation angles was quantified through building energy simulations of a case building in Turkey. The most schools in Turkey do not comply with the current energy code because they were built prior to the code. Thus, there is a crucial need to investigate their energy efficiency for potential retrofits. The results of the study exemplified how the breakdowns in energy use and carbon emissions would significantly influence design decision-making process of a school. Considering the four climate scenarios, mainly the influence of an orientation angle on energy use intensity (EUI) is higher than its influence on carbon emissions. This study differed from other sustainability researches in terms of defining building massing in schools with an emphasis on environmentally climate responsive school design, which is a holistic approach and comprehensive understanding of high-performance energy efficiency. A climate responsive massing should address the questions beyond well-known standards, and define a new holistic model that uses the optimum orientation, and surface to volume ratio of the building to reduce energy loads and achieve high-performance energy efficiency.

1 Introduction

School buildings play a critical role to contribute to the health and well-being of every society [1]. Schools represent a unique environment that differ from other building types, given that in a school, there are four times more occupants per square meter than in a typical office building [2]. Occupants spend much of their time inside classrooms. This occupancy schedule patterns make school buildings responsible for a significant portion of the total energy consumption of the non-residential sector. Schools require special attention on sustainable building managements so that early

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Y. Afacan (✉)
Department of Interior Architecture and Environmental Design, Bilkent University, Ankara, Turkey
e-mail: yasemine@bilkent.edu.tr

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decisions on building massing, classroom layouts, geometry parameters and spatial configurations of each function have critical impact on energy efficiency. Previous massing studies in schools have largely focused on solely plan layout, such as linear, corridor etc., and compactness of geometrical shape parameters related to different typologies [3], such as L-C-U-H shapes, linear corridor or central with different classroom dimensions, pavilion, slabH, slabV and courtyard types etc., to compute energy performance of schools [4–6]. However, compactness of a shape is not always the optimal solution for energy efficiency [7–9]. Even with the same shape, it is not possible to have well-specified energy measures for schools [9].

Although there are a number studies on the relationship between energy efficiency and building forms in developed countries, there is a lack of studies analysing correlations among energy use, different climate scenarios and building orientations of similar massing typologies in developing countries, such as Turkey. In Turkey, in recent years due to the difficulty of producing different projects for each school considering diverse range of climate types, time constraints, staff shortage and financial problems, the production of a typical project application has become more intense. Thus, this study investigates how the energy efficiency of a similar building massing varies depending on the four climate zones and simulates a typical Turkish school building in the four representative cities at the four different orientation angles. Based on the results of climate zone assessments, it proposes a simulation-based climate proofing in order to define a set of proper massing parameters and to decide the correlations among massing typologies, different climate zones and the key energy loads of schools, such as heating, cooling etc.

2 Energy Impacts of School Typologies

Energy impacts of buildings have been discussed first in United Nations Brundtland Commission in 1987, then UN Commission Report in 1992 on sustainable development and Kyoto Conference by UN Framework on climate change. In 2002 European Energy Efficiency Directive [10] investigated building optimization to reduce their impacts on energy consumption. In 2012 and 2018, net zero energy buildings have been presented by the European Directives [11, 12]. Hence, most of the school buildings both in Europe and in most of the countries around the world were built before those dates of the directives so that they could not satisfy energy efficiency directives [13]. Thus, there are lots of studies exploring energy efficiency in school buildings, measures related to building envelope, and enhance energy performance through environmentally responsive design.

There are uncertainties in energy performance of schools depending on the country, location and climate zones. Reviewing the literature on the energy impacts of school typologies showed that there are many different definitions of typologies and energy consumption patterns accordingly. Some studies defined typology classifications as massing types based on the overall configurations [14–16]; whereas the others described it based on the proportions of a 2D drawing [17, 18]. Afacan and

Ranjbar [9] investigated the five most commonly used school massing typologies in the contemporary school architecture: (1) Spine/street—major school functions along a central linear space; (2) City/town—a loose type of massing with more potential of legible school functions; (3) Atrium- a full height atrium serving passive solar design, thermal inertia and access outside views; (4) Strawberry/cluster—a central core providing circulation; and (5) Courtyard—flexible layout around the courtyard with enhanced energy efficiency benefits. These typologies did not differ according to the age of the students. They were prevalent for primary, secondary and high schools. They found significant differences in terms of annual energy use, annual energy cost and annual carbon dioxide (CO_2) emissions among the massing types, and suggested a new holistic model based on the ratio of surface area to volume more for reducing energy loads of a typical high-performance schools [9].

According to the Statistics of the Turkish Ministry of National Education, there are 25.5 million students which means that one third of the Turkey's population spends the majority of their time in school buildings [19]. In the academic year of 2017–2018 in Turkish primary and high schools, about 18 million students taught by 1 million teachers in total 66,000 schools [20]. Thus, school buildings in Turkey have a great importance in energy consumption. The total energy consumption of non-residential sector in Turkey has increased 174% compared to the energy consumption in 1990. The schools contribute 23% to this total energy consumption, which forces the educational building retrofit to tackle this challenge [19]. Due to their high-energy consumption, high occupant density and high activity patterns, schools represent a significant category among the other building typologies to be responsible for a considerable amount of energy consumption. In UK and US, school buildings are responsible for 10% and 13% of total energy consumption respectively [13]. Since Turkey has experienced a considerable surge in energy demand [21], achieving energy efficiency in current school building stocks becomes crucial because sustainable design, planning and construction decrease energy consumption by reducing environmental pollution, controlling energy waste patterns, maintenance and transportation costs [7].

With regards to the European Energy Efficiency Directives, in 2000 Turkey considered energy efficiency measures for the schools that were newly constructed, but the majority of the existing schools were constructed before 2000 without a focus on energy performance and were not gone any energy refurbishment later on. In Turkey, typical school projects were designed by the Ministry of Public Works to be used in all regions until the year 1970 [20]. Later, in 1980, there were minor revisions in these typical projects regarding regional energy differences. After 1997, when 5-year compulsory primary education was extended to 8 years. The adaptation of existing buildings was mostly done with the addition of floors, which ignored the relationship between energy demand and massing typology.